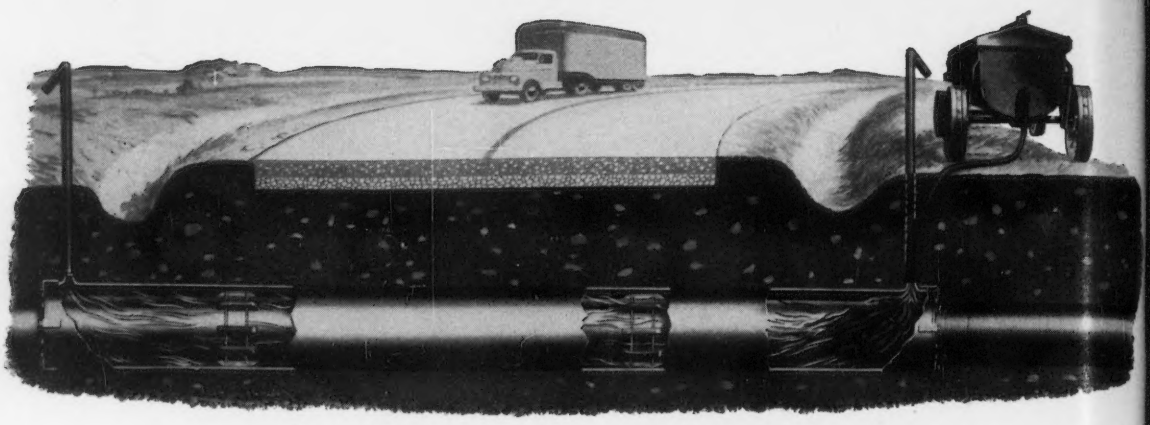
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Vol. 5 DECEMBER, 1949 No. 12



Cutaway of highway crossing showing application of NO-OX-ID Casing Filler. Here 24" pipe has been pushed through a 28" casing; casing bushings assembled and sealed at the ends. Filler is feeding from the portable melting kettle directly into the lower casing vent coupling.

New...

PROTECTION FOR CASED PIPE LINES

Under Highways, Railroads, or River Crossings

Now another fine product has been added to the list of NO-OX-ID protectors for pipe lines.

This time it's NO-OX-ID Casing Filler which seals casings easily and economically, eliminates the damage which occurs when coated pipe is pulled or pushed through highway, railroad, or river crossing casings.

NO-OX-ID Casing Filler, applied through casing vents to the bare pipe, fills the annular space between pipe and casing, providing complete protection to the sealed-off section.

As application is made after bushings have been installed and casing openings sealed, the liquid NO-OX-ID completely displaces the entrapped air, bonds readily and firmly to the casing wall and pipe, and solidifies to a firm jell. Chemical inhibitors prevent all corrosion.

Get this Latest Descriptive Bulletin

Save Damage to Coatings . . . Get Lasting Rust Prevention, New Ease in Handling this underground operation. The new Bulletin furnishes complete information.

Dearborn Chemical Company
310 South Michigan Avenue
Chicago 4, Illinois

Please send me your new Bulletin featuring NO-OX-ID Casing Filler.

Name_____
Address_____
City_____
State_____

NO-OX-ID IRON-CLAD RUST

Dearborn
Reg. U. S. Pat. Off.

THE LEADER IN RUST PREVENTIVES AND BOILER WATER TREATMENT

DEARBORN CHEMICAL COMPANY

310 S. Michigan Ave., Chicago 4 • 807-15 Mateo St., Los Angeles
205 E. 42nd St., New York • 2454 Dundas St., West, Toronto

We have coated and wrapped more than 200 million feet of pipe, sizes ½" to 60" both inside and outside (and that's a lot of pipe in anybody's language). Ninety-six (96) of the top hands in the business.

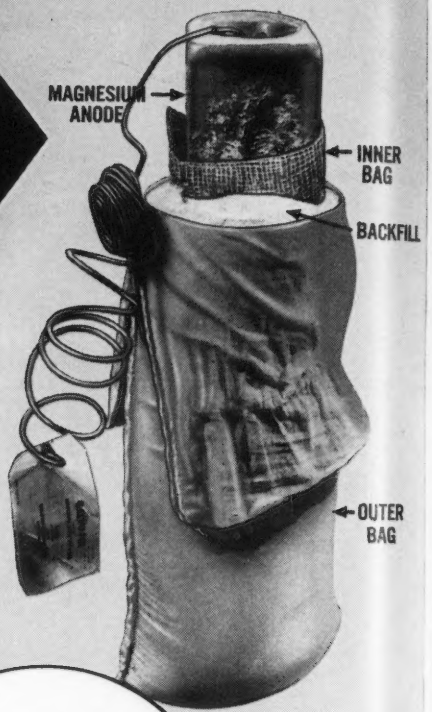
By the addition of more and better equipment, we are ABLE, WILLING AND READY to handle both your new and used pipe jobs. Complete reconditioning services available.

"PUTTING *Permanence* IN PIPE"

MAYES BROS. INCORPORATED HOUSTON

GALVO-PAK

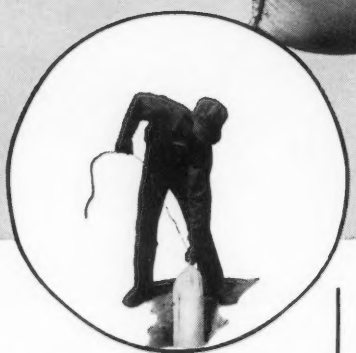
(TRADEMARK REGISTERED)



DOWELL'S *packaged*

MAGNESIUM ANODE

- protects buried metals
- cuts installation costs . . .
- assures maximum performance



Galvo-Paks, Dowell's packaged magnesium anodes,* simplify the installation of cathodic protection systems for pipelines, tanks and other buried metal structures. Their use eliminates the costly, troublesome practice of mixing bulk backfill, insures proper placement of the anode in the backfill, and gives maximum performance.

Galvo-Paks are Dowell magnesium anodes packed with a specially prepared, quick-wetting backfill material in cloth sacks. On the job, Galvo-Paks are simply dropped into augured holes. The bag within a bag insures proper centering of the anode.

Galvo-Pak is a product of Dowell, a subsidiary of The Dow Chemical Company,

*Patented and patents pending.

pioneer in the protection of buried metal with magnesium. Dowell offers a complete line of magnesium anodes alloyed to specifications designed for maximum efficiency and long life. Dowell anodes require no external power and cut maintenance costs to a minimum. Ask for a copy of the new 16 page booklet on the uses, design and installation of a Dowell cathodic protection system.

DOWELL INCORPORATED
TULSA 3, OKLAHOMA
Offices in Principal Cities

FREE SHOWING!

Now available—a new 16 minute sound slide film illustrating the possibilities of Dowell magnesium anodes for corrosion control. A Dowell representative will gladly arrange a special showing at your plant, office or organization meeting.

DOWELL

MAGNESIUM ANODES

GALVO-PAK • GALVO-LINE

A SUBSIDIARY OF THE DOW CHEMICAL COMPANY

Look to DOWELL

MAGNESIUM ANODES FOR CORROSION CONTROL

THIS MONTH'S COVER—S. S. Marine Chemist is shown at Dow Chemical Company docks at Freeport, Texas loading chemicals for delivery on the East Coast. Caustic soda, glycol, carbon tetrachloride and other solvents will be her principal cargo. Special conversion additions included double bulkheads and inert linings for tanks for caustic soda and ethylene glycol. A more detailed description may be found on Page 7 in the News Section.

☆

STAFF

Editorial

IVY M. PARKER
Editor

NORMAN E. HAMNER
Managing Editor

Correspondents

B. B. MORTON
Non-Ferrous Metals

HENRY W. FOELSCH
Pulp, Paper, Mining and Food

ABBA H. THOMAS
Ferrous Metals

E. R. BEGOLE
Petroleum Production and Transportation

IRWIN C. DIETZE
Power

GUSTAVE HEINEMANN
Chemical Process

R. H. BROWN
Light Metals

DERK HOLSTEYN
Petroleum Refining

J. M. STANDRING
Telephone, Telegraph, Radio

R. MCFARLAND
Non-Metals

L. M. MOSHER
Transportation Industry

A. J. GATES
Water Works

Advertising

A. B. CAMPBELL
(Executive Secretary of NACE)
Advertising Manager

☆

GENERAL OFFICES

919 Milam Building
803 Texas Avenue
Houston 2, Texas

Subscription: $7.50 per year to non-members; Member's dues $7.50, of which $3.00 are applied as subscription to CORROSION; Special rate, $3.50 per year for public and educational libraries. Additional copies to members 50 cents, to non-members 75 cents. Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds.

Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

Corrosion is Indexed Regularly by Engineering Index.

Corrosion *devoted entirely to*

CORROSION

Research and Control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., to provide a permanent record of progress in the control of corrosion as described in papers prepared for the Association and from other sources.

VOL. 5 DECEMBER, 1949 No. 12

CONTENTS

Page

Directory of Regional and Sectional Officers ... iv
Improvement in Corrosion Inhibitors Science and Technology Is Aim of TP-9
By A. Wachter ... xi

TECHNICAL SECTION

The Behavior of Bituminous Pipe Coatings Under Bending Vibrational Stress
By Dr. W. Beck ... 405
Correlation Between Corrosion Survey Results and Actual Conditions as Determined Through 130 Miles of Continuous Reconditioning
By I. B. Tietze ... 409
Discussion: R. J. Emerson, Page 414; J. C. Stirling, Page 415
Topic of the Month—Cathodic Protection of Marine Tractor
By Oliver Osborn ... 416
Marine Boiler Deterioration
By I. G. Slater and N. L. Parr ... 417
Corrosion Problems in the Pulp and Paper Industry
By Dr. Roy P. Whitney ... 435
Plant Corrosion in the Fatty Acid Industry
By R. J. Paul ... 439
Discussion: M. A. Scheil, Page 442.

INDEX TO VOLUME 5 – 1949

Contents Pages by Months ... 444
Technical Committee Activities ... 445
Technical Practices Committee Reports ... 445
Correlating Committee on Cathodic Protection ... 445
Titles Alphabetically by First Indicative Word ... 446
Authors Alphabetically ... 448
Corrosion Abstracts, Subjects, By Months, Pages ... 450

NACE NEWS SECTION

North East Region News ... 1, 2, 3
South Central Region News ... 1, 6
New NACE Section Organized in Baltimore ... 1
Tulsa Section Plans Corrosion Short Course ... 1
14 Papers Tentatively Scheduled for St. Louis ... 2
Philadelphia Section Changes December Meeting Date ... 2
Four Papers Presented at North East-Pittsburgh Meeting ... 3
Policy on Publication of Papers Amended ... 4
"Corrosion Problems" To Be Handled by E. A. Tice ... 6
NACE New Members, Address Changes ... 8
New Products, Materials, Literature ... 9
Essential Information for Authors of Technical Papers ... 12

CORROSION ABSTRACTS SECTION

	Page		Page
Atmospheric	13	Surface Preparation	18
Cathodic Protection	14	Testing	20
Construction Material	16	Water	20

Index to Advertisers ... 21

Copyright 1949 by the National Association of Corrosion Engineers. Reproduction of the contents, either as a whole or in part, is forbidden unless specific permission has been obtained from the Editor of CORROSION. Articles presented represent the opinions of their authors, and not necessarily those of the Editors of CORROSION, nor the Officers or Members of the National Association of Corrosion Engineers. Manuscripts to be considered for publication should be forwarded, together with illustrations, to the Editor of CORROSION, 919 Milam Building, Houston 2, Texas.

Directory of NACE Regional and Sectional Officers

NORTH EAST REGION

R. H. LYNCH, Director
Keystone Pipe Line Co.,
260 South Broad Street,
Philadelphia 1, Penna.

N. P. PEIFER, Chairman
Mfgrs. Lt. and Ht. Co.,
Pittsburgh, Penna.

L. B. DONOVAN, Sec.-Treas.
Cons. Edison Co. of N. Y., Inc.
4 Irving Place,
New York 3, New York

• Metropolitan Section (N.Y.)

T. P. MAY, Chairman
International Nickel Co., Inc.
67 Wall Street
New York 5, N. Y.

H. W. WAHLQUIST, Vice-Chair.
Ebasco Services, Inc.,
2 Rector Street,
New York, N. Y.

F. J. LeFEBVRE, Sec.-Treas.
Electro Rust-Proofing Corp.
(N. J.)
1 Main Street,
Belleville 9, N. J.

• Philadelphia Section

H. L. HAMILTON, Chairman
Keystone Pipe Line Co.
260 S Broad Street,
Philadelphia, Penna.

A. V. SMITH, Vice-Chair.
Consulting Engineer,
370 Trevor Lane,
Bala-Cynwyd, Pa.

E. R. ENGLISH, Sec.-Treas.
H. C. Price Co.,
P. O. Box 6120,
Philadelphia 15, Penna.

• Baltimore Section

EDGAR F. WOLF, Chairman
Cons. Gas Electric Light and
Power Co. of Baltimore,
531 East Madison St.,
Baltimore 3, Md.

HOMER D. HOLLER, Vice-Chairman
National Bureau of Standards,
Room 207, East Building,
Washington 25, D. C.

GEORGE E. BEST, Sec.-Treas.
Mutual Chemical Co. of Am.,
1348 Block Street,
Baltimore 31, Md.

• Pittsburgh Section

RUSSELL H. COE, Chairman
Pittsburgh Coke & Chemical
Co., P. O. Box 1645,
Pittsburgh 19, Pa.

V. V. KENDALL, Vice-Chairman
National Tube Co.,
Box 266,
Pittsburgh, Pa.

J. M. BIALOSKY, Treasurer
Carnegie-Illinois Steel
Corp., 210 Semple St.,
Pittsburgh 13, Pa.

E. D. VERINK, JR., Secretary
Aluminum Co. of America,
P. O. Box 1012,
New Kensington, Pa.

W W. BINGER, Asst. Secretary
Research Laboratories,
Aluminum Co. of America,
New Kensington, Pa.

NORTH CENTRAL REGION

N E. BERRY, Director
Servel, Inc.
119 N. Morton Ave.,
Evansville, Ind.

L. G. VANDE BOGART, Chairman
Crane Co., Engineering & Res.
Div., 836 South Michigan Ave.
Chicago 5, Illinois

WALTER J. SANDEL, Vice-Chair.
Coatings for Industry, Inc.
2185 East 18th Street,
Cleveland 15, Ohio

R. A. SHOAN, Sec.-Treas.
Dearborn Chemical Company,
1029 West 35th Street,
Chicago 9, Illinois

• Chicago Section

J. PAT CASEY, JR., Chairman
Crane Company,
836 South Michigan Ave.,
Chicago 5, Illinois

V. J. PAYTON, Vice Chair.
Commonwealth Edison Co.,
72 W. Adams Street,
Chicago 90, Illinois

• Cleveland Section

E. W. VEREEKE, Chairman
Heil Process Equip. Corp.
12901 Elmwood Ave.,
Cleveland, Ohio

RAYMOND B. HOXENG, Vice-Chair
University Circle
Case Institute of Tech.
Cleveland, Ohio

J. A. THORNTON, Sec.-Treas.
Cleveland Tool & Supply Co.
1427 W. 6th Street,
Cleveland, Ohio

• Greater St. Louis Section

PHILIP H. SMITH, Chairman
Nooter Boiler Works,
St. Louis, Mo.

FRANK L. WHITNEY, JR.,
Vice-Chairman
Monsanto Chemical Co.,
St. Louis, Mo.

E. L. RICE, Sec.-Treas.
National Lead Co.,
St. Louis, Mo.

WM. F. GROSS, Corres.-Sec.
Tretolite Co.,
937 Pacific Ave.,
St. Louis 19, Missouri

SOUTH EAST REGION

JAMES T. MacKENZIE, Director
Amer. Cast Iron Pipe Co.,
P. O. Box 2603,
Birmingham 3, Alabama

E. O. RANGE, Chairman
The Okonite Company,
1606 Rhodes Haverty Bldg.,
Atlanta, Georgia

J. W. YELDELL, Vice-Chair.
So. Natural Gas Co.,
P. O. Box 2563,
Birmingham, Alabama

E. D. McCAULEY, Sec.-Treas.
American Cast Iron Pipe Co.
P. O. Box 2603,
Birmingham 2, Alabama

SOUTH CENTRAL REGION

L. F. SCHERER, Director
Texas Pipe Line Co., Box 2332,
Houston 1, Texas

TOM R. STATHAM, Chairman
Magnolia Pipe Line Co.,
Dallas, Texas

GEORGE A. MILLS, Vice-Chair.
Central Power & Lt. Co.,
Corpus Christi, Texas

M. C. FLEMING, Sec.-Treas.
Phillips Petroleum Co.,
Bartlesville, Okla.

HARRY E. WALDRIP, Ast. Sec.-
Treas.
Gulf Oil Corp.,
Houston, Texas

• Tulsa Section

I. B. TIETZE, Chairman
Phillips Petroleum Co.,
P. O. Drawer B,
Bartlesville, Oklahoma

A. S. MUNNEKE, Vice-Chair.
Stanolind Pipe Line Co.
Box 591,
Tulsa, Oklahoma

JOHN W. ELDER, Sec.-Treas.
John W. Elder Company,
310 Thompson Building,
Tulsa, Oklahoma

• Houston Section

JACK L. BATTLE, Chairman
Humble Oil & Ref. Co.
P. O. Box.2180
Houston 1, Texas

A. L. STEGNER, Vice-Chair.
Tennessee Gas Trans. Co.
P. O. Box 2511
Houston 1, Texas

PERRY P. SPAFFORD, Sec.-Treas.
Stanolind Oil & Gas Co.
P. O. Box 3092
Houston 1, Texas

• Shreveport Section

M. W. BELSON, Chairman
D. E. Stearns Co.
P. O. Box 1234
Shreveport, La.

H. V. BEEZLEY, Vice-Chair.
United Gas Corp.,
Shreveport, La.

M. J. OLIVE, Secretary
Arkansas Natural Gas Co.
Shreveport, La.

J. A. CREEVY, Treasurer
Youngstown Sheet & Tube Co.
Shreveport, La.

• North Texas Section

K. D. WAHLQUIST, Chairman
6281 Revere Place
Dallas 14, Texas

JOHN R. LIGON, Vice Chair.
Sinclair Ref. Co.
901 Fair Bldg.
Ft. Worth, Texas

JOHN L. POOL, Sec.-Treas.
Magnolia Pipe Line Co.
618 Magnolia Bldg., Box 900
Dallas, Texas

N. H. SIMPSON, Asst. Sec.-Treas.
Consol. Vultee Aircraft Corp.
Grants Lane
Ft. Worth, Texas

• Corpus Christi Section

HUGH WILBANKS, JR., Chairman
Gas Dept., City of Corpus
Christi, P. O. Box 111,
Corpus Christi, Texas

GEO. A. MILLS, Vice Chair.
Central Power and Light Co.
120 North Chaparrol St.,
Corpus Christi, Texas

E. L. RANKIN, Sec.-Treas.
Republic Pipe Line Co.,
Box 2166,
Corpus Christi, Texas

• Permian Basin Section

AARON GENSBERG, Chairman
Gulf Oil Corp.,
Drawer 4232
Odessa, Texas

H. D. MURRAY, Vice-Chair.
The Texas Co.,
Box 1270
Midland, Texas

ROY H. ZUEFELDT, Sec.-Treas.
The Texas Co.,
P. O. Box 903,
Jal, New Mexico

• Sabine-Neches Section

M. A. FURTH, Chairman
Pure Oil Company,
Nederland, Texas

D. L. BURNS, Vice-Chair.
Gulf Oil Corp.,
Box 701,
Port Arthur, Texas

R. S. FREEMAN, Sec.-Treas.
Tutwiler Refinery,
Cities Serv. Ref. Corp.,
Lake Charles, La.

(Continued Next Page)

Directory of NACE REGIONAL and SECTIONAL OFFICERS

WESTERN REGION

I. C. DIETZE, Director
Dept. of Water and Power,
City of Los Angeles,
141 South Martel Avenue,
Los Angeles, California

HARRY J. KEELING, Chairman
Southern Counties Gas Co.
of Calif., 810 South Flower,
Los Angeles 14, California

ERNEST O. KARTINEN, Vice Chair.
Signal Oil and Gas Co.,
811 West Seventh Street,
Los Angeles 14, California

E. R. STAUFFACHER, Sec.-Treas.
Southern Calif. Edison Co.,
P. O. Box 351,
Los Angeles 53, California

• San Francisco Bay Area Section

ROBERT T. EFFINGER, Chairman
Shell Oil Co., Inc.,
Martinez, California

RICHARD S. TRESEDER, Vice Chair.
Shell Development Co.,
Emeryville, California

ARTHUR E. STORM, Sec.-Treas.
Tidewater Associated Oil Co.,
Avon, California

• Salt Lake City Section

Temporary Officer

HARRY BROUGH, Chairman
Mountain Fuel Supply Co.
Salt Lake City, Utah

PRE-PRINTS

"CAUSES OF CORROSION IN AIRPLANES AND METHODS OF PREVENTION," By N. H. Simpson, Chief Chemist, Consolidated Vultee Aircraft Corp., Fort Worth Division, Fort Worth, Texas.

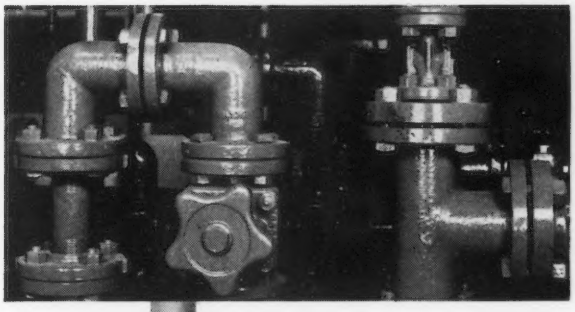
"CONTROL OF VAPOR ZONE CORROSION IN STORAGE TANKS BY THE USE OF AMMONIA," By F. T. Gardner and A. T. Clothier, The Carter Oil Co., and Francis Coryell, Interstate Oil Pipe Line Co., Tulsa, Okla.

Papers Presented at the NACE
SOUTH CENTRAL REGION
MEETING, OCT. 3-4
Dallas, Texas

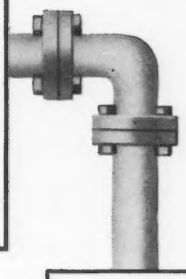
Order from CENTRAL OFFICE, NACE
919 Milam Bldg., Houston, Texas

PER COPY
Postpaid 50c

★
for dependable protection against corrosion



specify
saran lined steel pipe



For the dependable protection against corrosion that assures you of long term operation at a minimum maintenance cost—SPECIFY Saran Lined Steel Pipe. Saran's unusual resistance to most chemicals and solvents plays an important part in the reduction of shut-downs and lost production. Another noteworthy advantage is its ease of field fabrication—involving NO costly delays with special tools or handling. Saran Lined Steel Pipe is available in maximum lengths of 10 feet and in sizes from 1 to 6 inches. Also available are allied fittings and plug valves, also saran lined. Write today for further information concerning Saran Lined Steel Pipe. Manufactured by The Dow Chemical Company, distributed nationally by the Saran Lined Pipe Company.

★ *readily field fabricated!*

★ *available immediately!*

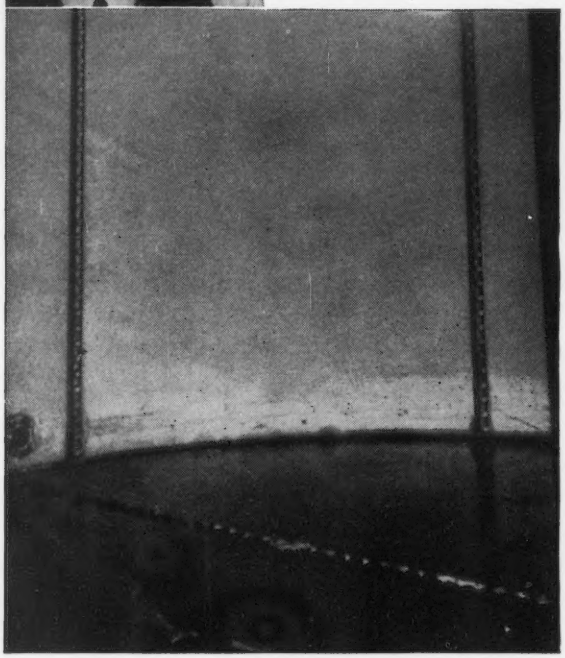
★ *lower in cost!*

SARAN LINED PIPE COMPANY
702 Stephenson Building
Detroit 2, Michigan

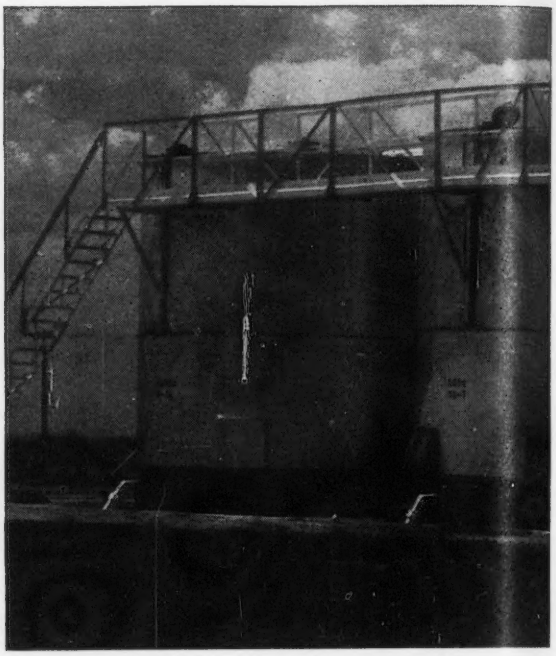
Offices in: New York • Boston
Philadelphia • Pittsburgh • Chicago
Tulsa • Indianapolis • Houston
San Francisco • Los Angeles
Portland • Seattle • Denver
Toronto

DOW
CHEMICALS INDISPENSABLE TO INDUSTRY AND AGRICULTURE

Inside story proves 3M protective coatings' amazing resistance to sour crude



STORAGE TANK INTERIOR, McElroy Lease, Texas. After two years exposure, "Coro-Gard" coating in good condition. Tank metal unaffected by corrosion.



STORAGE TANK EXTERIORS can also be given lasting protection and neat appearance with "Coro-Gard" coatings. Flat, glossy, or anti-skid finishes are available.

Get longer tank life with anti-corrosion "Coro-Gard"

When a better, more dependable protective coating for crude-oil storage tanks is needed, choose "Coro-Gard". Tank life is increased, corrosion damage lowered.

This synthetic-resin coating has been tested and proved under the most strenuous conditions. It guards metal against chemical fumes or spillage, salt or fresh water spray or immersion, high humidity, solvents, petroleum impurities, many other caustics.

There are 15 basic "Coro-Gard" Protective Coating Systems, each developed to save you money on your specific service conditions. Why not ask our engineering department for free advice? No obligation.

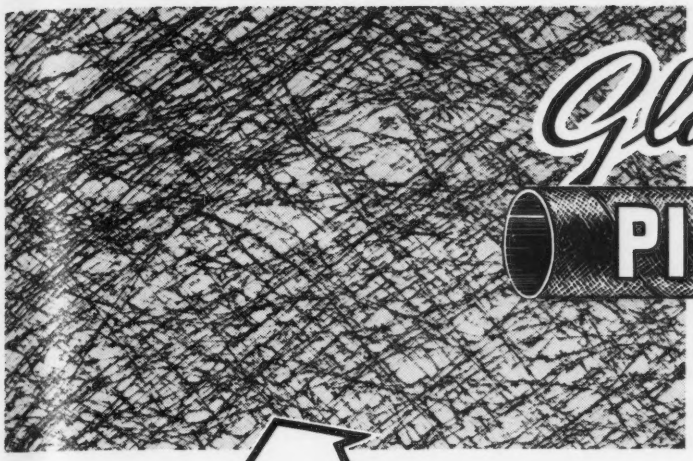
WRITE TODAY for complete information about cutting the cost of treating equipment, prolonging the interval between coating and re-coating. Address our Adhesives and Coatings Division in Detroit.

CORO-GARD
BRAND
ANTI-CORROSION COATING

Made in U. S. A. by **MINNESOTA MINING & MFG. CO.**
Also makers of "Scotch" Brand Pressure-sensitive Tapes, "Underseal" Rubberized Coating, "Scotchlite" Reflective Sheeting, "Safety-Walk" Non-Slip Surfacing, "3M" Abrasives, "3M" Adhesives.

ADHESIVES & COATINGS DIVISION
411 Piquette Avenue, Detroit 2, Michigan
General Offices: St. Paul 6, Minn.

General Export: DUREX ABRASIVES CORP., *New Rochelle, N. Y.*
In Canada: CANADIAN DUREX ABRASIVES LTD., *Brantford, Ontario*



Glasfloss PIPE WRAP

DISTRIBUTED EXCLUSIVELY BY

PERRAULT Brothers INC.

1130 N. BOSTON • TULSA 6, OKLA.

Actual enlarged photograph of Glasfloss Pipe Wrap showing uniformity and continuity of the glass fibers.

TENSILE STRENGTH

Continuous glass fibers running full width of mat.

POROSITY

Long glass fibers arranged in a pattern that gives maximum porosity.

BINDER

Coal tar derivative.

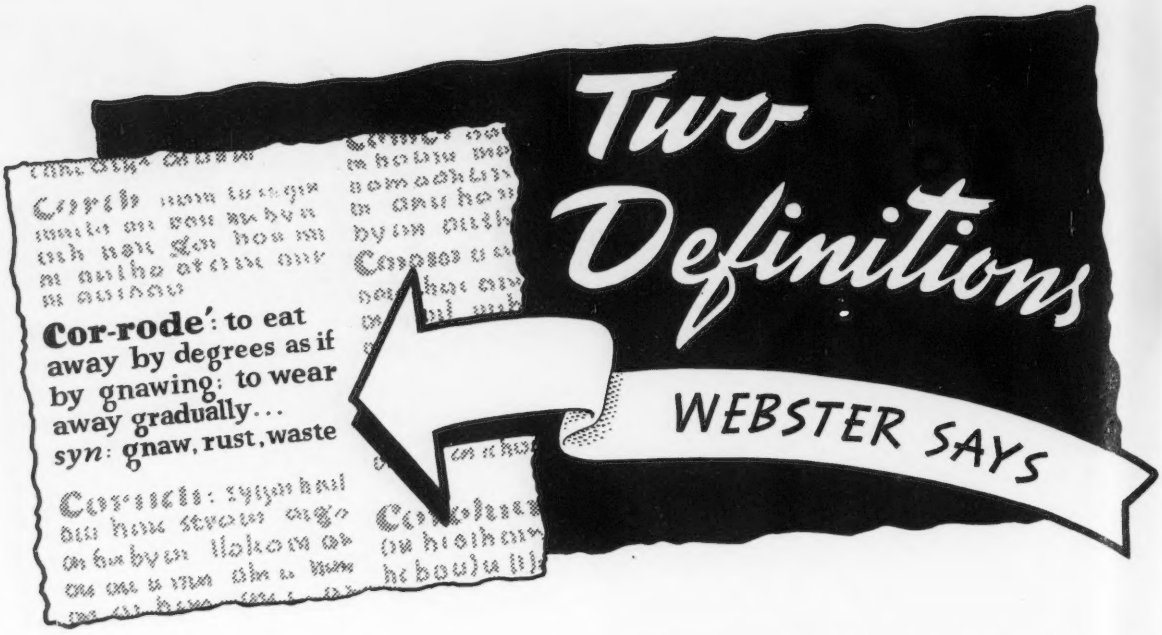
Available for immediate shipment...

from our Tulsa warehouse, or from factory at Hicksville, N. Y., in 400 foot rolls in widths 3", 4", 6", 9", 12", 18" and in 800 foot rolls in widths 9", 12", and 18".

PERRAULT Brothers

TELEPHONE 5-1103 • 1130 NORTH BOSTON • TULSA, OKLA.

EXPORT OFFICE: 30 ROCKEFELLER PLAZA, NEW YORK 17, N. Y.



The Pipeliner Says, "CORROSION ? An A-No. 1 Headache!"

Two Answers from MIDWESTERN

OWENS-CORNING COROMAT

UNDERGROUND PIPEWRAP

Now Midwestern is stocking the new Owens-Corning COROMAT, an improved underground pipewrap that offers an increase in tensile and tear strength ranging from 200% to 400%. COROMAT is a porous mat of glass fibers reinforced with long, continuous strands of Fiberglas Yarns integrated into the wrap in a multi-directional pattern. This added strength eliminates breakage in application and allows higher wrapping speeds and use of longer rolls. Midwestern's proven service assures prompt delivery from any one of four warehouses located in Tulsa, Houston, Kansas City and Newark.

GLASFAB

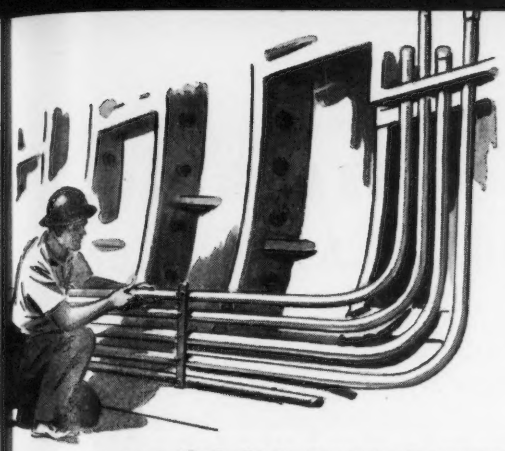
GLASFAB, the new hydrocarbon thermoplastic impregnate Fiberglas cloth is now in wide use for hand wrapping "hot spots," field joints, field repairs and for machine-wrapping river crossings and "hot lines." Like Coromat it is impervious to moisture and heat, compatible with coal tar or asphalt coatings and has good porous characteristics. Also, GLASFAB has a high tensile strength — 92 pounds per inch — and is soft, pliable and non-irritating to the hands. GLASFAB comes in lengths 150-foot to 1200-foot rolls with widths from 2 to 36 inches.

WRITE MIDWESTERN FOR MORE DETAILED INFORMATION

MIDWESTERN ENGINE & EQUIPMENT CO., INC.

105 N. Boulder, 15 S. W. 29th St. — TULSA, OKLAHOMA, OKLAHOMA CITY, OKLAHOMA — Phone 3-4113, Phone 7-4342

HOUSTON, TEX.	PITTSBURGH, PA.	SHREVEPORT, LA.	ALBUQUERQUE, N. M.
D. E. HUGHES	JOHN R. WILSON	TOM L. HOLCOMBE	IRA B. BRINER
5030 Arvilla Lane	555 McCulley, McKeesport, Pa.	Drawer 248, Cedar Grove Sta.	4629 N. 11th
Lehigh 9551	McK 2-5461	7-0241	2-7598



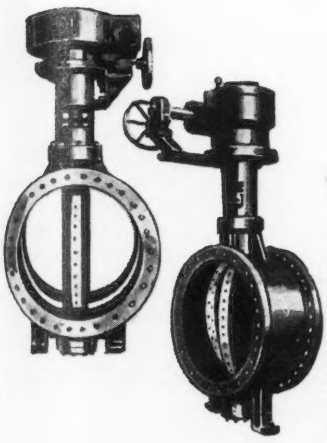
NO PLACE FOR REPLACEMENTS HERE!

... so the nation's biggest underwater tunnel uses Everdur† Electrical Conduit to carry traffic light and control cables. New York's Triborough Bridge and Tunnel Authority, builders of the Brooklyn-Battery Tunnel, made selection on the basis of long-time service records on comparable installations.

WELL, WELL, WELL, WELL

That's right, four of 'em. 38" diameter slotted well screens of Everdur, built by the Layne-Northern Company of Mishawaka for Elkhart, Indiana's water supply. Reasons: strength, weldability, machinability, corrosion resistance ... and nary a trace of rust!

†REG. U. S. PAT. OFF.



TRAFFIC CONTROLS

Down from the Alvarado Regulating Reservoir rushes the water supply for San Diego at 100-lb. pressure. Many of the vital parts of these mechanical traffic cops are made of Everdur for long operating life. These big butterfly valves, up to 42" I. D., were made by Coldwell-Wilcox Division of Krajewski-Pesant, New York.

HAPPY THOUGHT IN A SQUALL!

When thunderheads race up and your boat lays over on her beam's end — you pray everything will hang together. That's the time to be thankful for your boat builder's judgment in using strong, tough, non-rust Everdur fastenings

... and speaking of seagoing metals, the Design Engineering Company of South Pasadena, California, developed this marine shell block of Everdur. Maximum strength and minimum weight are combined in this one-piece, folded-and-drawn, rivetless block construction. 49190

"DID YOU KNOW" DEPARTMENT

Maybe it never occurred to you that many belt-drive applications require a non-magnetic, spark-resistant lacing. Well, they do. And the Flexible Steel Lacing Company of Chicago makes 'em under the trade name "Alligator." Out of Everdur, of course.

P.S. HOW ABOUT SENDING IN YOUR STORY ON EVERDUR?

WHAT'S YOUR METAL PROBLEM?

Maybe Everdur can help. Our Technical Department is always ready to serve. Just write to The American Brass Company, Waterbury 88, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

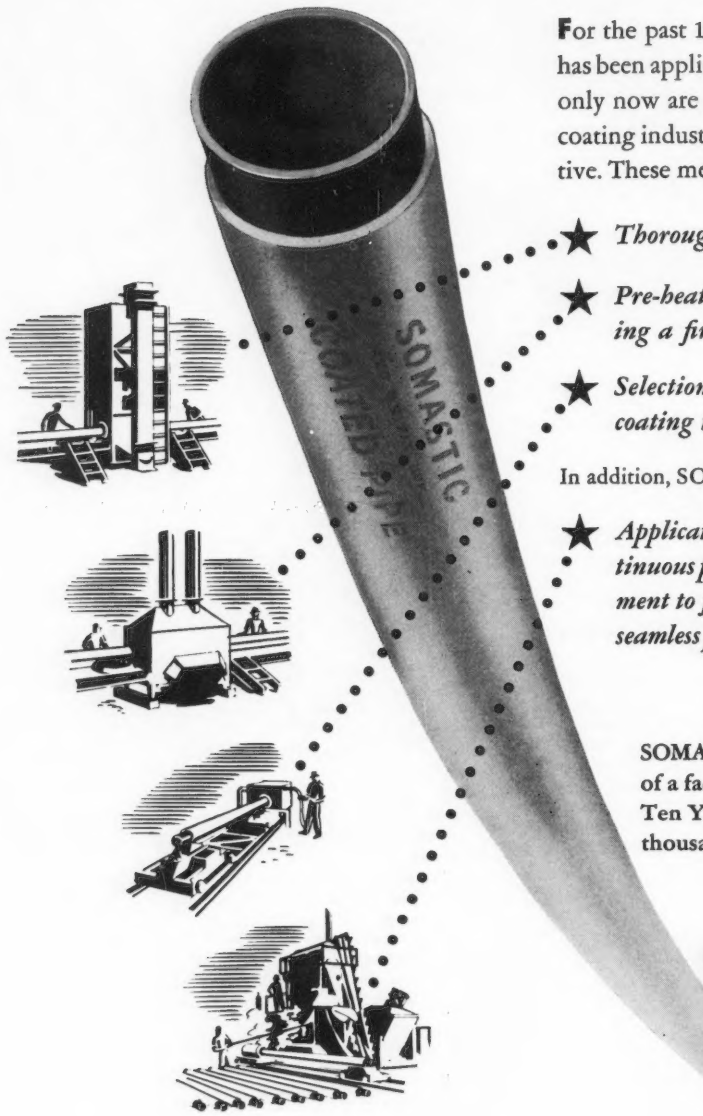
Where corrosion resistance counts

ANACONDA

COPPER-SILICON ALLOYS*

SOMASTIC* PERMANENCE

includes TIME TESTED METHODS of Application



For the past 19 years SOMASTIC PIPE COATING has been applied to pipe by standard practices which only now are being adopted generally by the pipe coating industry. Time has proved them most effective. These methods are—

★ *Thorough cleaning of metal by grit-blasting.*

★ *Pre-heating, followed by hot priming, assuring a firm, lasting bond of coating to steel.*

★ *Selection of materials and manufacture of coating to rigid specifications.*

In addition, SOMASTIC leads in this essential feature—

★ *Application of coating to primed pipe in a continuous process by special* SOMASTIC *equipment to form a dense, compact, uniform and seamless protective coating of great durability.*

The general swing to methods pioneered by SOMASTIC Pipe Coating is another acknowledgment of a fact first shown by the API-Bureau Of Standards Ten Year Pipe Coating Tests . . . and since proved at thousands of corrosive locations.

SOMASTIC
*Reg. U. S. Patent Office
PIPE COATING

Unequaled for PERMANENT PROTECTION

MANUFACTURED BY

H. C. PRICE CO.
Somastic Division
BARTLESVILLE, OKLAHOMA
In the 37 States East of the Rocky Mountains

BECHTEL CORPORATION
SAN FRANCISCO and WILMINGTON
CALIFORNIA
In the 11 Western States and in Foreign Countries

Improvement in Corrosion Inhibitors Science And Technology Is Aim of TP-9

By A. WACHTER*

INHIBITORS are widely used in industry for the prevention or control of corrosion, often with unique success. There is no doubt that the application of corrosion inhibitors is an exceedingly useful method for the prevention of corrosion. However, there exists considerable confusion and misunderstanding regarding their behavior and on effective methods for using them. There is room for great improvement in the science and technology of corrosion inhibitors. Committee TP-9 on Corrosion Inhibitors was established to work toward the accomplishment of such improvements. The committee thus far has been concerned mainly with the organization of its membership, with consideration of general aims and objectives, and with decisions regarding initial activities in this field. The membership at present is small and is composed of individuals who are active and well-known workers in the field. It was agreed that the primary aims of the committee should be to obtain and to make available information on corrosion inhibitors, to promote the proper use of inhibitors, to promulgate best technical practices for evaluation of corrosion inhibitors, and to encourage research on inhibitors.

There are many industrial fields in which corrosion inhibitors are used and probably many more in which they may become important. It seems that the committee might eventually be active in all of the following kinds of industrial applications for corrosion inhibitors: acid pickling, oil pipelines, cooling water, potable water, boiler water, refrigerating brines, radiator coolants, oil wells, chemical processing, finished products in containers, air-conditioning, lubricating oil, sterilizing solutions, oil well acidizing, and metal cleaning. Owing to the large number of different industrial applications for corrosion inhibitors, it was considered advisable to undertake only one field at the start. It was agreed to begin with the field of pickling acid inhibition since this familiar use seems to offer favorable opportunities for development of the committee's mode of action, and perhaps for positive accomplishment. As an initial activity on this subject, a questionnaire has been prepared which it is planned to send to a large number of commercial suppliers of pickling acid inhibitors and to many industrial users of such inhibitors. The main objectives of the questionnaire are to discover the technical information required by a consumer to select the product best suited for his needs and to arrive at uniform and significant test procedures for evaluating the performance of such inhibitors.

When a corrosion engineer is confronted with a problem which might be solved by means of an inhibitor, he is compelled to reflect upon the criteria for the selection and for the evaluation of corrosion inhibitors. There are few, if any, established guides for his thinking along these lines and the technology of corrosion inhibition appears largely haphazard. The less prominent inhibitors frequently are overlooked entirely, and rarely is full consideration given to all technical aspects prior to use of a corrosion inhibitor. The result is the prevailing attitude that the usefulness of an inhibitor can only be judged by full-scale trial, and their frequent misuse with disappointing results. This situation constitutes a real challenge to the efforts of the Inhibitor Committee.

The committee would welcome suggestions on possible worthwhile activities as well as information on inhibitors. The committee is confident that it can count on the cooperation of the NACE membership in accomplishing its objectives. Communications to the committee should be addressed to the Chairman: A. Wachter, Shell Development Company, 4560 Horton Street, Emeryville 8, California.

* Chairman of Committee TP-9 on Corrosion Inhibitors. Shell Development Co., Emeryville, Calif.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

Officers, 1949-50

President.....R. B. MEARS
Pittsburgh, Pa.

Vice-President.....VANCE N. JENKINS
Wilmington, Cal.

Treasurer.....O. C. MUDD
Houston, Texas

Executive Secretary.....A. B. CAMPBELL
919 Milam Building
Houston 2, Texas

Directors

President

R. B. MEARS.....1949-50
Carnegie-Illinois Steel Corporation, Pittsburgh, Pa.

Vice President

VANCE N. JENKINS.....1949-50
Union Oil Company of Cal., Wilmington, Cal.

Treasurer

O. C. MUDD.....1949-50
Shell Pipe Line Corp., Houston, Texas

Representing Active Membership

PAUL W. BACHMAN.....1949-52
Davison Chemical Corp., Baltimore, Md.

L. J. GORMAN.....1948-51
Consolidated Edison Co. of New York, Inc., New York, N. Y.

MAYNARD H. JACKSON.....1949-50
Middle West Coating & Supply, Tulsa, Okla.

Representing Corporate Membership

D. C. GLASS.....1949-52
Pure Oil Company, Chicago, Ill.

WARD R. MYERS.....1949-51
E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

JOHN M. PEARSON.....1947-50
Sun Oil Company, Philadelphia, Pa.

Representing Associate Membership

E. D. VERINK, JR.....1949-52
Aluminum Co. of America, New Kensington, Pa.

D. E. STEARNS.....1948-51
The D. E. Stearns Co., Shreveport, La.

TOM L. HOLCOMBE.....1947-50
Holcombe & Stearns, Inc., Shreveport, La.

Representing Regional Divisions

ROBERT H. LYNCH.....North East
Keystone Pipe Line Co., Philadelphia, Pa.

N. E. BERRY.....North Central
Servel, Inc., Evansville, Ind.

L. F. SCHERER.....South Central
Texas Pipe Line Co., Houston, Texas

IRWIN C. DIETZE.....Western
Dept. of Water & Power, City of Los Angeles, Calif.

J. T. MACKENZIE.....South East
American Cast Iron Pipe Co., Birmingham, Ala.

Directors Ex Officio

F. L. LAQUE, Past President, 1949-50
The International Nickel Co., Inc., New York, N. Y.

E. P. NOPPEL, Chairman
Policy and Planning Committee
Ebasco Services, Inc., New York, N. Y.

MARS G. FONTANA, Chairman
Technical Practices Committee
Ohio State University, Columbus, Ohio

IVY M. PARKER, Chairman
Publication Committee
Plantation Pipe Line Co., Bremen, Ga.

L. A. BALDWIN, Chairman
Regional Management Committee
Johns-Manville Sales Corp., New York, N. Y.

The Behavior of Bituminous Pipe Coatings Under Bending Vibrational Stress*

By DR. W. BECK*

1. Problem and Experimental Procedure

Sections on an underground pipe line in a large city were corroded considerably if located near points with heavy traffic. The pipe, although covered with a reinforced asphalt layer, was attacked locally. Portions of the line crossing districts with traffic vibrated, while other sections did not oscillate at all. On concrete foundations located near the pipe line, vibration frequencies between 10-50 cycles/sec could be measured during traffic hours.

According to these observations it can be assumed that the coating was exposed to the influence of a bending vibrational stress.

The question arose whether or not these stresses exerted an unfavorable influence on the durability of a bituminous covering.

An attempt was made to answer this question by studying the process of crack formation in a coating on a vibrating pipe, by measurements of the electric resistance and corrosion observations.

The apparatus shown in Figure 1 was used to generate vibrations on a pipe.

A section of a steel pipe having a total length of 78.7 inches was clamped between two self-aligning ball bearings. The length of the clamped pipe section was 63 inches. The outer diameter of the steel pipe was 1.38 inches and its wall thickness 0.02 inches. By connecting one end of the tubing to an eccentric drive, vibrations could be set up in a vertical direction. Various bituminous coatings were applied to the metal surface on four short sections. The protected pipe sections were surrounded by a short aluminum tube having a diameter of 2.16 inches and a length of 6.3 inches. The interspace between coating and aluminum pipe was filled with moist soil. Lower temperatures could be applied by filling the pipe with a suitable cooling medium.

The pipe was put under a reversed bending stress, and an intermittent cycle of vibration and cooling was used. For eight hours the tube was in movement and for 16 hours at rest. In general during the period of oscillation the pipe was kept for 2.5 hours at a temperature of —17° C. The total number of cycles was indicated by a cycle counter.

An attempt to intensify the corrosive conditions was made by applying an electrical potential to the cells. An emf of three volts was kept constant during the total time of exposure with resistance as shown in Figure 1. A system of switches made it possible to follow potential drop and current flow in the various cells separately. The measurements of resistivity were made at +25° C.

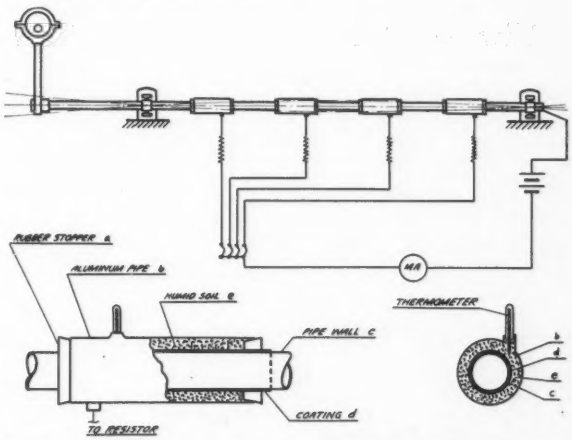


Figure 1—Apparatus for studying the influence of bending vibrational stresses on bituminous coatings.

Knowledge with regard to the mechanism of deformation of a bituminous material at various temperatures is very limited; therefore, a calculation of the bending stress is not yet possible. In this investigation the breakdown of the protective layer system was followed by a decrease of its insulating properties in proportion to the number of stress cycles applied.[1] The frequency of vibration was kept constant at 10 cycles/sec. and the deflection varied.

★ Submitted for publication March 23, 1949.
[1] Corrosion Research Laboratory, Department of Metallurgical Engineering, Lehigh University, Bethlehem, Pa.

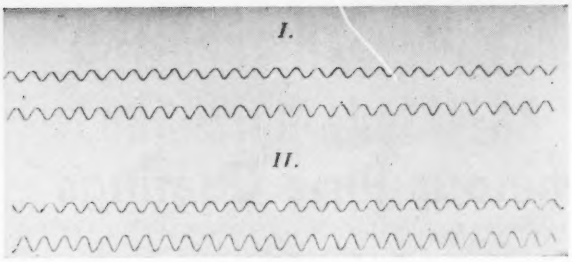


Figure 2—Oscillogram taken on the vibrating pipe. I—pipe empty. II—pipe filled with cooling medium.

Figure 2 shows some oscillograms recorded on several points of the vibrating and coated pipe. The oscillograms under I were taken on an empty pipe; the *upper* record was taken at a distance of 24.9 inches from the mid-point of the steel pipe, and the *lower* record at the mid-point.

The lines under II were recorded on the pipe after filling with the cooling medium. The *upper* line was taken again at a distance of 24.9 inches from the mid-point, and the *lower* one at the mid-point.

The Tables I and II give more mechanical data. The acceleration of gravity was calculated from known formulae. The deflection at a given point was ascertained by its distance from the center of the oscillating system and the amplitude at the mid-point with aid of the equation of the elastic line.

TABLE I
Measured deflections and acceleration of gravity. Four sections of pipe covered with coatings I-IV

lx	a	g	a^1	g^1
0	0.107	435.5	0.124	509.45
24.9	0.030	120.9	0.034	128

TABLE II
Calculated deflections and acceleration of gravity

Number	lx	a	g	a^1	g^1
I	21.65	0.043	177.6	0.051	209.8
II	21.65	0.043	177.6	0.051	209.8
III	7.28	0.093	380	0.110	450
IV	7.28	0.093	380	0.110	450

Notations:
lx—Distance from mid-point of pipe in inches.
a—Deflection in inches.
g—Acceleration of gravity (inch/s^2)
a, g—Means pipe empty.
a^1, g^1—Means pipe filled with cooling medium.

2. Bituminous Coatings

The four coatings applied to the steel surface were as follows:

No. I—An asphalt impregnated cord 0.079 inches in diameter was wound spirally around the hot pipe and completely coated with asphalt. This layer was reinforced by an asphalt saturated cotton wrapper (osnaburg type), and asphalt was poured over the rotating pipe. The thickness of the whole layer system was 0.158 inches.

No. II—The molten asphalt was poured over the hot pipe rotating at a constant speed. A second application followed in order to obtain a thickness of about 0.138 inches.

No. III—Asphalt was poured over the rotating hot pipe. Immediately following this operation a jute bandage impregnated with the same material was wrapped into the hot asphalt primer. After this, a layer of asphalt was applied, while the pipe was rotated, giving a total thickness of 0.158 inches.

No. IV—The pipe was cold wrapped with a grease-impregnated bandage, and completely covered with molten asphalt to a total thickness of 0.158 inches. The softening point of the asphalt used in the coatings was between 60° and 70° C. The layers were applied after degreasing the metal surface by rubbing with cotton, wet with carbon tetrachloride.

3. Discussion of Experimental Results

Figures 3, 3a, and 4 show the experimental results on the protective system designated No. II, consisting of two layers of asphalt. Curve IIa in Figure 3 illustrates the relation between total resistance and stress cycles of layer system II in which the temperature is kept constant at +25° C. Similarly Curve II shows the results when the specimen is cooled periodically. Due to crack formation, the current distribution is not homogeneous so the resistance is not referred to a unit of area but to the total surface of the asphalt layer.* In Figure 3a the change in resistance is plotted against the time of vibration. The specimen represented by Curve IIa is deflected 0.043 inches during the 496-hour test. The deflection of the specimen for Curve II is 0.043 inches during 88 hours and 0.051 inches for 40 hours. Total time of vibration was 128 hours. There were 40 hours of cooling.

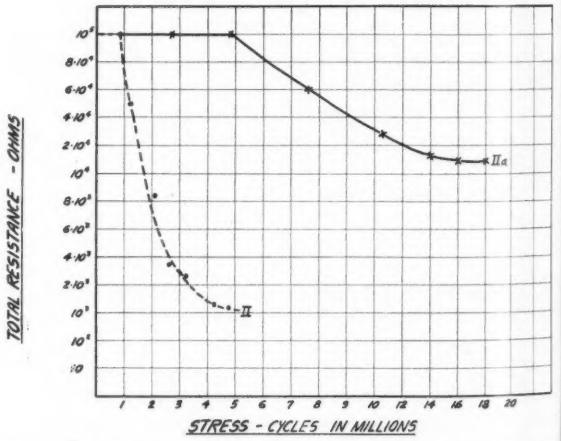


Figure 3—Resistance of a coating consisting of two layers of asphalt (No. II) vs number of stress cycles. No. IIa—temperature kept constant at + 25° C. No. II—cooled periodically.

* An accurate measurement of resistances 10^5 Ohms could not be accomplished with the used measuring device. A coating having a resistance of this magnitude will behave practically like an insulator.

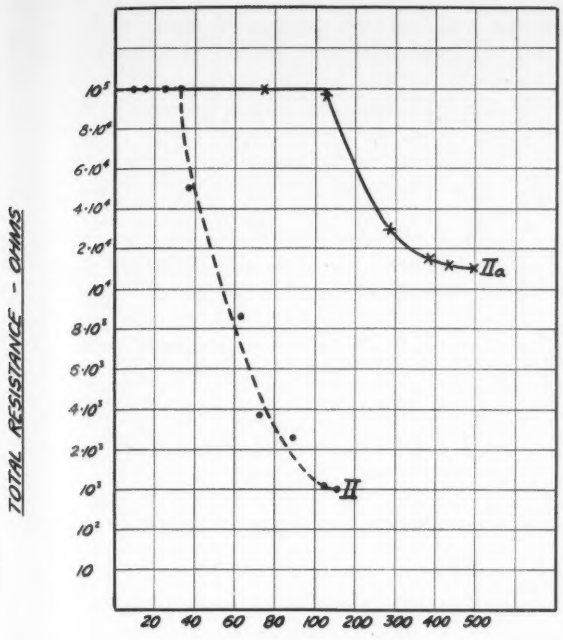


Figure 3a—Resistance of coating No. II vs time of vibration.

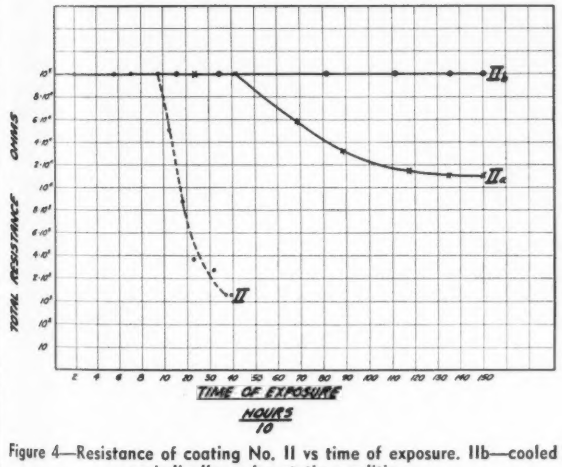


Figure 4—Resistance of coating No. II vs time of exposure. IIb—cooled periodically under static conditions.

In Figure 4 the total resistance is plotted against the total time of exposure. In the run designated No. IIb, the pipe section was covered by two non-reinforced layers of asphalt, which were cooled periodically under static conditions. No. II has the same significance as in Figures 3 and 3a.

The resistance as a function of the number of stress cycles taken on the four protective systems is plotted in Figure 5.

The results of measurements given in the Figures 3-5 can be discussed as follows: Line IIa in Figure 3 makes it evident that there is a decrease in resistance of this layer at room temperature under dynamic conditions. No breakdown occurs at static conditions, notwithstanding the fact that the pipe was cooled

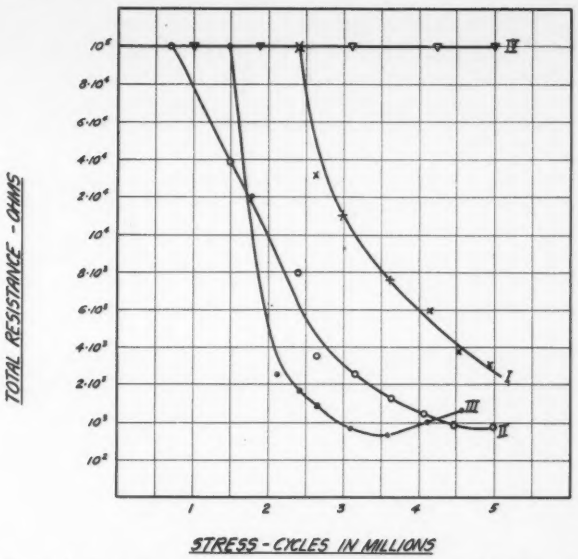


Figure 5—Resistance of various protective coatings vs number of stress cycles. Test specimens exposed to the influence of bending vibrational stresses and cooled periodically. Surface areas of coatings Nos. I, II, and IV are 27.9 sq. in. Surface area of coating No. II is 27.66 sq. in.

periodically with a potential difference applied (Line IIb in Figure 4). It is only the non-reinforced asphalt layer which shows a limited resistance drop even at room temperature under dynamic stress. Figure 5 makes it evident that the decrease of resistivity is very steep on layers No. I, No. II and No. III if cooled periodically, and after a relatively short time of exposure the material is almost completely disintegrated. Similar results with regard to the formation of cracks under dynamic stress and low temperature were obtained without applying an emf. at all.

The above results make it evident that the simultaneous action of low temperature and vibration are the determining factors causing the breakdown of the reinforced asphalt coverings.

It follows from Figure 5 that a decrease in the insulating properties of the covering does not occur before a certain critical value of stress cycles is exceeded. Table III gives the critical number of stress cycles and the corresponding time of vibration.

TABLE III

No.	Critical No. of Stress Cycles in Millions	Time of Vibration Hours	Time of Cooling Hours
II	0.8	22.2	6.9
III	1.5	41.6	13
I	2.4	66.6	20.8
IIa	5.0	139	0
IV	> 5.0	> 139	> 43.4

As shown in Table II the deflections in III and IV are larger than in I and II.

The resistance against cracking is very low in system II, higher in III, and still higher in I and IIa while in IV no change in the insulating properties could be found.

Pictures of the surface of the pipe sections after removal of the various layers at the end of the exposure test are shown in Figure 6. The first pipe section from left was covered with two layers of asphalt (No. II). A great number of corroded zones, mostly in form of scratches, can be distinguished on the steel surface. The next section, pipe protected by the grease wrapping (No. IV), does not indicate any corrosive attack. On the last two photographs showing pipe sections originally covered by the reinforced coatings I and III a certain number of scratches are also visible.

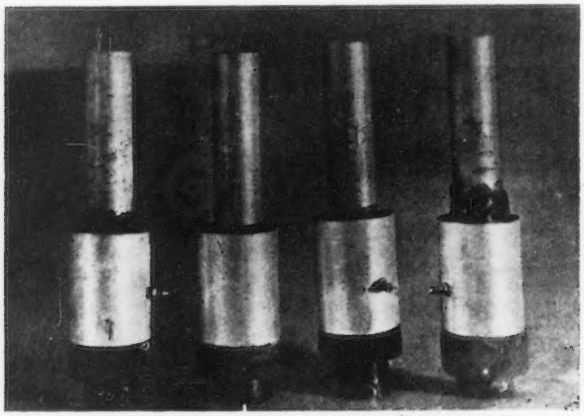


Figure 6—Condition of various pipe sections after removal of coatings. Left to right: Nos. II, IV, III, I.

After finishing the experiment IIa (influence of vibration without cooling) only a small metal attack could be detected. A picture does not show the slight differences between No. IIa and No. IV.

The unsatisfactory behavior of non-reinforced bituminous coatings applied to pipe lines in service[2] is in agreement with the results of the mechanical and corrosion test.

The good behavior of the system No. IV, consisting of a grease wrapper covered by an asphalt layer, deserves special consideration.

The above experimental results make it probable that in case of a coincidence of special circumstances, such as long lasting periods of hard frost and heavy traffic vibrations, an unfavorable effect on the durability of certain kinds of bituminous coatings can occur.

As shown in Figure 5, all coverings containing asphalt can support a number of stress cycles before cracks are formed. Exceeding a limiting value of stress cycles, which is different for the various types of coatings applied, the material shows brittle fracture, especially at low temperature.

The characteristic behavior of the coatings in the above described endurance test can be interpreted as a fatigue phenomenon.

Fatigue also can be observed in high polymers and is intimately tied up with the molecular structure of these substances.

Knowledge with regard to the molecular structure of asphalts is very limited. These substances probably can be classified as polymers with low or medium molecular weight having a polycyclic structure.[3,4] It is hoped that further investigations of strength and fatigue in bituminous substances will give more information with regard to their molecular structure. It will be especially instructive to study the process of crack formation by varying the bending stress and the frequency of vibration at various temperatures. Such measurements were started with a modified apparatus as described in Figure 1, but they could not be continued in consequence of the outbreak of war.

Summary and Conclusions

Reinforced and non-reinforced asphalt coatings and a wrapping impregnated with petroleum grease were applied to the surface of a steel pipe and exposed to the influence of bending vibrational stresses. With the exception of the grease bandage, all layer systems, when submitted to the simultaneous action of low temperature and oscillation, showed brittle fracture and fatigue. The process of crack formation was followed by measurements of the electric resistance and corrosion observations. The tests indicate the possibility that low temperatures and vibration from heavy traffic will adversely affect the life of certain bituminous coatings on underground pipe lines.

References

1. W. Beck, *J. of Telephone Engineering*, **7**, 13 (1935).
2. J. Campbell Stirling, *Corrosion*, **1**, 19 (1945).
3. E. S. Hillman and B. Barnet, *Proc. ASTM*, 37, 566 (1937).
4. Ch. Mack, *J. of Physic. Chem.*, **362**, 2911 (1932).

The assistance of Dr. A. Bahrd in the experimental part of this work is appreciated.

Correlation Between Corrosion Survey Results And Actual Conditions as Determined Through 130 Miles of Continuous Reconditioning ★

By I. B. TIETZE

Abstract

The Phillips Petroleum Company has for many years used the corrosion survey as a means of locating corroded sections of pipe line. Although records were kept of leak locations and condition of pipe wherever uncovered for repairs or inspection, no conclusive evidence as to the accuracy of the survey was obtained. The continuous reconditioning of sizeable lengths of lines afforded a better means of determining this accuracy, and consequently provisions were made to gather the necessary data while the lines were uncovered for reconditioning.

This paper is concerned with the correlation of the data pertaining to pipe condition obtained during continuous reconditioning with corrosion survey recommendations. In addition to the correlation study, certain of the data are indicative of the effectiveness of a spot-reconditioning and coating program which had been followed in the past.

I. B. TIETZE

Presently assistant to the vice president and general superintendent of the Phillips Pipe Line Co., Mr. Tietze, excepting for five years of service in the field artillery, has been employed in pipe line corrosion mitigation, inspection, construction, economic studies and special engineering problems. A graduate of University of Missouri, 1936, with BS in civil engineering, he is an associate member of ASCE and chairman of Tulsa Section, NACE.

THIS paper is concerned primarily with the correlation between corrosion survey findings and actual pipe condition as found during continuous reconditioning. However, because an extensive program of spot reconditioning had been performed on one of the lines, and because this spot reconditioning had a pronounced effect on the correlation study, certain data relative to its effectiveness are presented.

The portions of pipe lines with which this study is concerned are shown on Figure 1, and are designated Sections A through D inclusive. Section A and B are portions of the Borger to Chicago 8-inch Products Pipe Line. Section A is approximately 24 miles in length and is within the Kansas flint hills, where corrosion was confined almost entirely to areas of salt water drainage. Section B is approximately 52 miles in length and passes through almost no oil field drainage. Corrosion within this section was a result of soil action.

Sections C and D are portions of the Oklahoma City to Kansas City 8-inch crude oil system. Section C is 50 miles in length and is composed of two portions of line, one 20 miles in length, and the other 30 miles in length, with approximately 12 miles between the two portions. This section passes through the Burbank Field where a large percentage of the corrosion occurred in oil field drainage areas. Section D is approximately six miles in length, and encounters no oil field drainage. Corrosion was a result of soil action.

These four sections were considered the most severely corroded section of the two systems. Sections A, B, and C were reconditioned over the trench with the lines in operation. Section D, the six mile section of 8-inch crude oil line, was replaced with 10-inch pipe.

History of Lines

The products pipe line (Sections A and B) was completed in 1931. The pipe 8⅝ inches O.D., 0.277-inch wall, 24.696 pounds/foot; joints were oxy-acetylene welded; nominal cover was 24 inches. The line was coated with a thin application of an asphalt chromate emulsion. This coating was applied to 63 percent of the line at a rate of five drums per mile, and to 35 percent of the line at the rate of nine drums per mile. To the remaining two percent of line the coating was applied either at a rate of nine drums per mile and shielded with a felt wrap, or at a rate of thirteen drums per mile with sand and cement included in the coating. No effort has been made to differentiate among the various types of coating in interpreting the results of this survey.

A visual corrosion survey was made over the entire Borger to St. Louis section of products line, Sections A and B having been covered in 1937. This survey consisted of walking the line and locating by visual means alone portions of line likely to be corroded.

A detailed corrosion survey covered these sections of the Products Line in 1938 and 1939. This survey consisted of measuring pipe-to-soil potentials (to copper sulphate) and line currents. The purpose of the survey was, of course, to locate corroded sections of line. Where there was no doubt that a corrosive condition existed, as evidenced by a peak in pipe-to-soil potentials and a loss in current, the section of

★A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.

Figure 1—Location of continuously reconditioned portions of pipe lines.

line was classed as "severe" and the section recommended for reconditioning. Where the readings contradicted each other, or where there was some doubt as to the severity of corrosion to be expected at a particular point, the section of line was classed as "doubtful." Within these "doubtful" sections, inspection points were recommended at the place where corrosion was expected to be most serious. The "severe" and "doubtfull" sections ranged in length from about 50 feet to 1500 feet. Portions not classed as "severe" or "doubtful" are referred to as "good."

A spot reconditioning program was inaugurated in 1939 and reconditioning was performed in accordance with corrosion survey recommendations. This program consisted of uncovering the pipe in "severe" areas and at inspection points. If the pipe was found to be severely corroded, stripping continued until good pipe was reached at both ends. If the pipe was found to be in good condition after inspection of the first portion uncovered, the entire section, whether "severe" or "doubtful" was not usually uncovered. Where necessary, welding repairs were made in the form of full sole, half sole, patches, or spot welds. Following the welding repair a 3/32-inch minimum thickness coal tar enamel coating was applied. On some of the earlier work the coating was not wrapped and a holiday detector was not used. However, this situation was soon corrected and in the later work the pipe was wrapped with a 15 pound coal-tar impregnated asbestos felt, and a holiday detector was passed over the coated pipe.

Cathodic protection was applied in certain areas of high leak frequency. Nine units have been installed on the two sections of the products line. Of these nine units, four are rectifiers, four are wind-driven units, and one is an engine generator. Each unit fully protects about one mile of line. The first unit was installed in 1939, the last in 1946.

The crude oil line (Sections C and D) was laid in 1933 of 8⅝-inch O.D. plain end pipe; joints were electric welded. New pipe weighing 24.696 pounds per foot was used in laying Section C; used pipe of varying weights was used in Section D. Nominal cover of both sections was 24 inches. Certain corrosive areas were coated with an asphalt chromate emulsion applied at a rate of five or nine drums per mile. Because only a small portion (8 percent) was covered with this virtually ineffective coating, this has been considered a bare line, and no attempt has been made to separate coated from uncoated sections in interpreting the results.

A detailed corrosion survey, similar to that previously described, was made on this line in 1942 and 1944. Very little spot reconditioning (only about 3½ percent of the total length) was performed in accordance with the recommendations of the corrosion survey.

Cathodic protection was installed at two locations of high leak rate. One of these units was an engine-generator, the other a wind-generator. Numerous cathodic protection spread tests were made at various locations, but current requirements for full protection were so great that a cathodic protection plan was abandoned.

Method of Survey

In performing this pit-depth survey, stationing was kept in accordance with line maps. All of the deepest pits on the external pipe surface were measured. The depth of the deepest pit on each 20-foot section of pipe surface was recorded when the maximum depth was less than 100 miles; when pitting 100 mils or greater in depth was encountered, the depth of the deepest pit was recorded for each five-foot section. Stationing was obtained on all half-sole, full-sole, patches, coating, etc., which had been applied during the spot-reconditioning program. These data were plotted on charts, each chart representing one mile of line, and from these charts results were tabulated.

Results

Results in condensed form are shown on Figures 2 to 7 inclusive, and Tables I to VI inclusive.

The results may be classified into two categories:

1. Data pertaining to the correlation between leak rate and corrosion survey findings.
2. Data pertaining to the correlation between pipe condition (as evidenced by pit depth measurements) and corrosion survey findings.

All figures and tables were developed from findings of the detailed and not the visual corrosion survey.

Leak Data

Figures 2 to 5 inclusive, show leak experience for Sections A to D respectively, prior to the time of continuous reconditioning. Three curves are included in each of the figures, showing:

1. Total leak experience.
2. Leak experience in "severe" and "doubtful" areas.
3. Leak experience in "good" areas.

The curve for leak experience in "severe" and "doubtful" areas in each case has been extended to estimate the number of leaks which would have occurred had no spot-reconditioning been done. A summary is also included, showing in tabular form the leak data from which the curves were constructed.

Attention is directed to the fact that in each of the

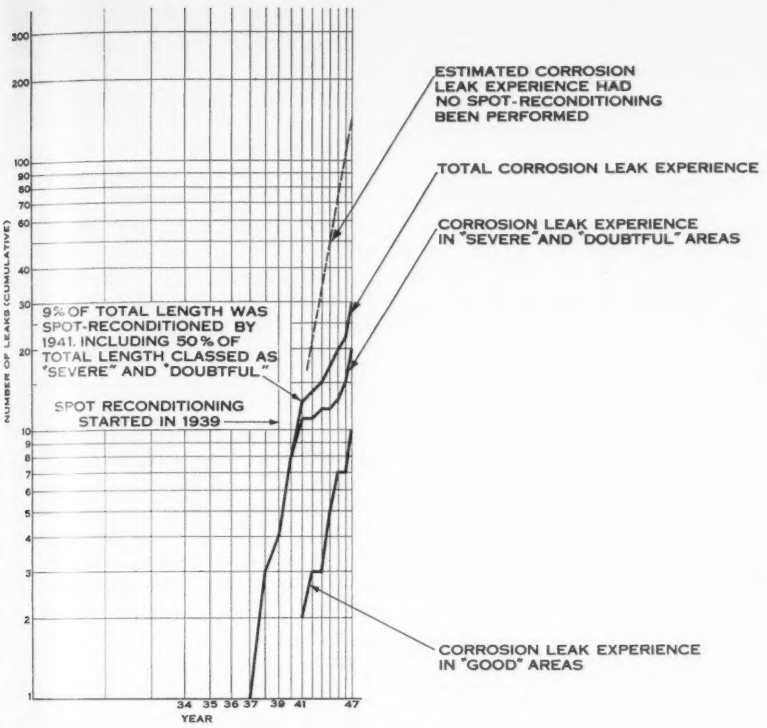

ESTIMATED CORROSION LEAK EXPERIENCE HAD NO SPOT-RECONDITIONING BEEN PERFORMED
TOTAL CORROSION LEAK EXPERIENCE
CORROSION LEAK EXPERIENCE IN "SEVERE" AND "DOUBTFUL" AREAS
9% OF TOTAL LENGTH WAS SPOT-RECONDITIONED BY 1941. INCLUDING 50% OF TOTAL LENGTH CLASSED AS "SEVERE" AND "DOUBTFUL"
SPOT RECONDITIONING STARTED IN 1939
CORROSION LEAK EXPERIENCE IN "GOOD" AREAS
NUMBER OF LEAKS (CUMULATIVE)
YEAR
34 35 36 37 39 41 47

Figure 2—Section A: Corrosion leak experience vs time.

Figure 2

Summary of Leaks by Years

YEAR	Number of Corrosion Leaks Each Year	Cumulative Total of Corrosion Leaks	Cumulative Total of Corrosion Leaks in "Good" Areas	Cumulative Total of Corrosion Leaks in "Severe" and "Doubtful" Areas
1937	1	1	0	1
1938	2	3	0	3
1939	1	4	0	4
1940	4	8	0	8
1941	5	13	2	11
1942	1	14	3	11
1943	1	15	3	12
1944	2	17	5	12
1945	3	20	7	13
1946	2	22	7	15
1947	8	30	10	20

NOTE: "Severe" and "Doubtful" Sections comprise 12 percent of the entire length; "Good" Sections 88 percent.

four sections, the leak experience in "severe" and "doubtful" sections exceeded the experience in "good" areas, although the length of "good" exceed the combined length of "severe" and "doubtful" by a ratio of almost four to one. The effect of spot-reconditioning in reducing the leak rate is evident on all four charts, and especially on the first two (Figures 2 and 3). Had no spot-reconditioning been done, the ratio between leaks in classified ("severe" and "doubtful") areas and leaks in "good" areas would have been increased materially. This is illustrated by the extensions of the curves showing leaks in "severe" and "doubtful" areas.

Table I shows the correlation between leak experience and corrosion survey classification. The number of corrosion leaks and percentage of the total leaks are recorded opposite the percentage of the total length of pipe found within each of the three categories. These figures are recorded for each of the four sections, and for a total of the four. They indicate that, over-all 51% of the leaks were experienced in the 10% of the total length classed as "severe," 16% in the 11% classed as "doubtful" and 33% in the 79% classed as "good." The above figures have not been corrected for the effect of spot-reconditioning in retarding the leak rate. Making this correction (using the extensions of the curves which appear in Figures 2 to 5 inclusive, for leaks in "severe" and "doubtful" areas) it is estimated that approximately 93% of the leaks would have occurred in the 21% of line classed as "severe" or "doubtful," and only 7% in the 79% classed as "good."

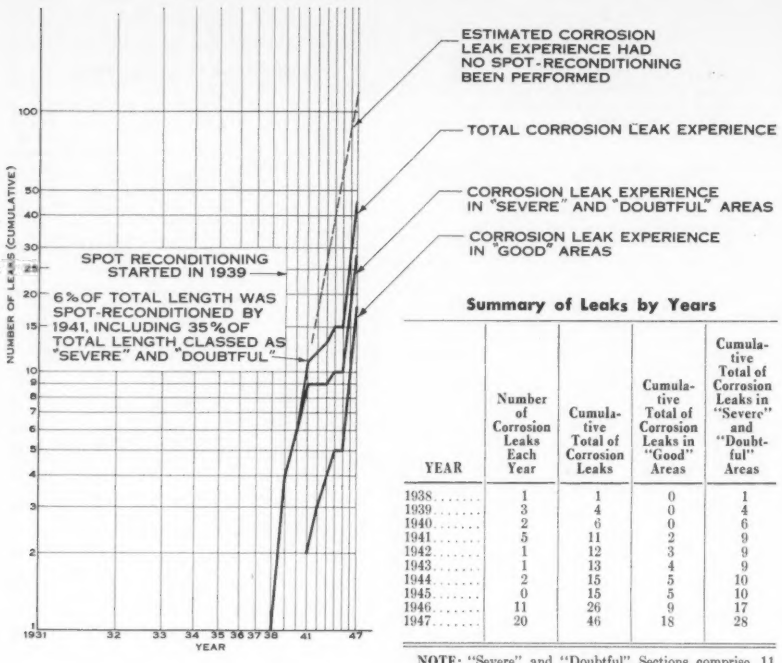
Another point which bears mentioning (although not directly a part of the correlation study it is significant as to rate of corrosion after spot-reconditioning) is the leak rate after spot-reconditioning as compared with that of the original line. In Sections A and B, 22 corrosion leaks were experienced within previously spot-reconditioned sections of line. Average time from reconditioning to leak was slightly over five years, the shortest one year, and the longest eight years. In other words, all 22 leaks occurred within eight years after spot-reconditioning. The 76 miles of line which comprises Sections A and B experienced no leaks in five years and only four leaks in eight years from the time originally put in operation. This increased rate of corrosion after spot-reconditioning is substantiated by the pit depth data which follow.

Pit Depth Data

Tables II through V show the number of five-foot sections containing various depths of pitting within "severe," "doubtful," and "good" areas. This is fur-

TABLE I—Correlation Between Corrosion Leak Experience and Corrosion Survey Classification

Corrosion Survey Classification	SECTION A			SECTION B			SECTION C			SECTION D			TOTAL		
	Number of Corrosion Leaks	Percent of Corrosion Leaks	Percent of Total Length Within Classification	Number of Corrosion Leaks	Percent of Corrosion Leaks	Percent of Total Length Within Classification	Number of Corrosion Leaks	Percent of Corrosion Leaks	Percent of Total Length Within Classification	Number of Corrosion Leaks	Percent of Corrosion Leaks	Percent of Total Length Within Classification	Number of Corrosion Leaks	Percent of Corrosion Leaks	Percent of Total Length Within Classification
Severe	14	47	5	16	35	5	184	52	18	27	71	13	241	51	10
Doubtful	6	20	7	12	26	6	52	15	16	4	11	16	74	16	11
Good	10	33	88	18	39	89	118	33	66	7	18	71	153	33	79
Total	30	100	100	46	100	100	354	100	100	38	100	100	468	100	100

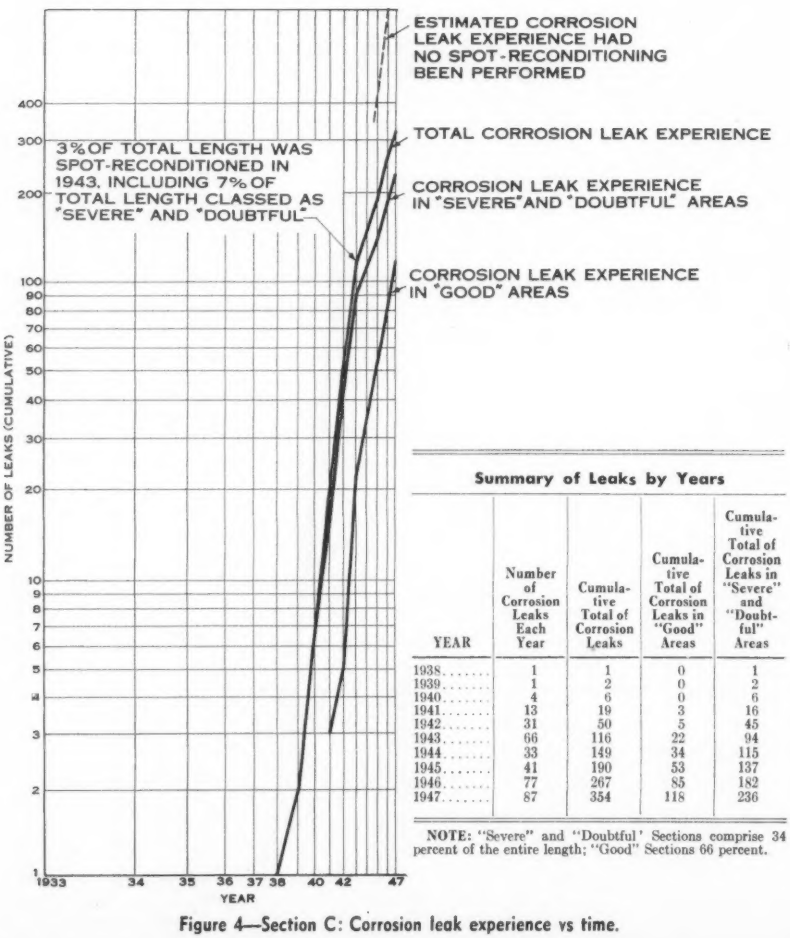

ESTIMATED CORROSION LEAK EXPERIENCE HAD NO SPOT-RECONDITIONING BEEN PERFORMED
TOTAL CORROSION LEAK EXPERIENCE
CORROSION LEAK EXPERIENCE IN "SEVERE" AND "DOUBTFUL" AREAS
CORROSION LEAK EXPERIENCE IN "GOOD" AREAS
SPOT RECONDITIONING STARTED IN 1939
6% OF TOTAL LENGTH WAS SPOT-RECONDITIONED BY 1941, INCLUDING 35% OF TOTAL LENGTH CLASSED AS "SEVERE" AND "DOUBTFUL"
NUMBER OF LEAKS (CUMULATIVE)
YEAR
1931 32 33 34 35 36 37 38 41 47

Summary of Leaks by Years

YEAR	Number of Corrosion Leaks Each Year	Cumulative Total of Corrosion Leaks	Cumulative Total of Corrosion Leaks in "Good" Areas	Cumulative Total of Corrosion Leaks in "Severe" and "Doubtful" Areas
1938	1	1	0	1
1939	3	4	0	4
1940	2	6	0	6
1941	5	11	2	9
1942	1	12	3	9
1943	1	13	4	9
1944	2	15	5	10
1945	0	15	5	10
1946	11	26	9	17
1947	20	46	18	28

NOTE: "Severe" and "Doubtful" Sections comprise 11 percent of the entire length; "Good" Sections 89 percent.

Figure 3—Section B: Corrosion leak experience vs time.


ESTIMATED CORROSION LEAK EXPERIENCE HAD NO SPOT-RECONDITIONING BEEN PERFORMED
TOTAL CORROSION LEAK EXPERIENCE
CORROSION LEAK EXPERIENCE IN "SEVERE" AND "DOUBTFUL" AREAS
CORROSION LEAK EXPERIENCE IN "GOOD" AREAS
3% OF TOTAL LENGTH WAS SPOT-RECONDITIONED IN 1943, INCLUDING 7% OF TOTAL LENGTH CLASSED AS "SEVERE" AND "DOUBTFUL"
NUMBER OF LEAKS (CUMULATIVE)
YEAR
1933 34 35 36 37 38 40 42 47

Summary of Leaks by Years

YEAR	Number of Corrosion Leaks Each Year	Cumulative Total of Corrosion Leaks	Cumulative Total of Corrosion Leaks in "Good" Areas	Cumulative Total of Corrosion Leaks in "Severe" and "Doubtful" Areas
1938	1	1	0	1
1939	1	2	0	2
1940	4	6	0	6
1941	13	19	3	16
1942	31	50	5	45
1943	66	116	22	94
1944	33	149	34	115
1945	41	190	53	137
1946	77	267	85	182
1947	87	354	118	236

NOTE: "Severe" and "Doubtful' Sections comprise 34 percent of the entire length; "Good" Sections 66 percent.

Figure 4—Section C: Corrosion leak experience vs time.

ther broken down into treatment afforded the line in the past for Sections A, B, and C. This breakdown includes 1) Original pipe surface untouched (i.e. areas where pipe has not been uncovered since it was laid), 2) Original surface, but within spot-reconditioned and coated sections, and 3) Added surfaces within spot-reconditioned and coated sections (by added surfaces is meant half-sole, casing, patches, etc.). Such a breakdown could not be made for Section D.

It is noteworthy also that within Sections A and B almost all deep pitting occurred in previously reconditioned portions of line (see Tables II and III). It appears the effect of spot-reconditioning and coating has been to concentrate and intensify pitting, with the result that pitting is deeper although perhaps not so wide-spread within previously spot-reconditioned and coated sections.

Table VI has been compiled from Tables II to V inclusive, and shows the correlation between depth of pitting and corrosion survey classification percentagewise. In all cases the correlation in the case of pitting in excess of 200 mils exceeded that for pitting in excess of 100 mils. Section D gave the poorest correlation, a large percentage of pipe having been found in areas classed as "good."

In order to compare the pit depth data equitably, the number of five-foot sections falling within each of the three categories have been expressed on a per mile basis. These are shown on Figures 6 and 7. Figure 6 shows the number of five-foot sections per mile containing pits in excess of 100 mils in depth, and Figure 7 those in excess of 200 mils in depth. The severity of corrosion found in Section D is evident from both figures. In fact, it will be observed that the "good" of Section D has more deep pitting than the "severe" of any of the other three sections.

Earlier, a visual survey was mentioned covering Sections A and B, in which an attempt was made to locate corroded sections of line by visual means alone. It is of interest to compare the accuracy of the two (visual and detailed) surveys for Sections A and B.

For Section A, the visual survey

TABLE II, SECTION A—Summary of Maximum Pit Depths by Five-Foot Sections, vs. Corrosion Survey Classification and Treatment Previously Afforded the Line

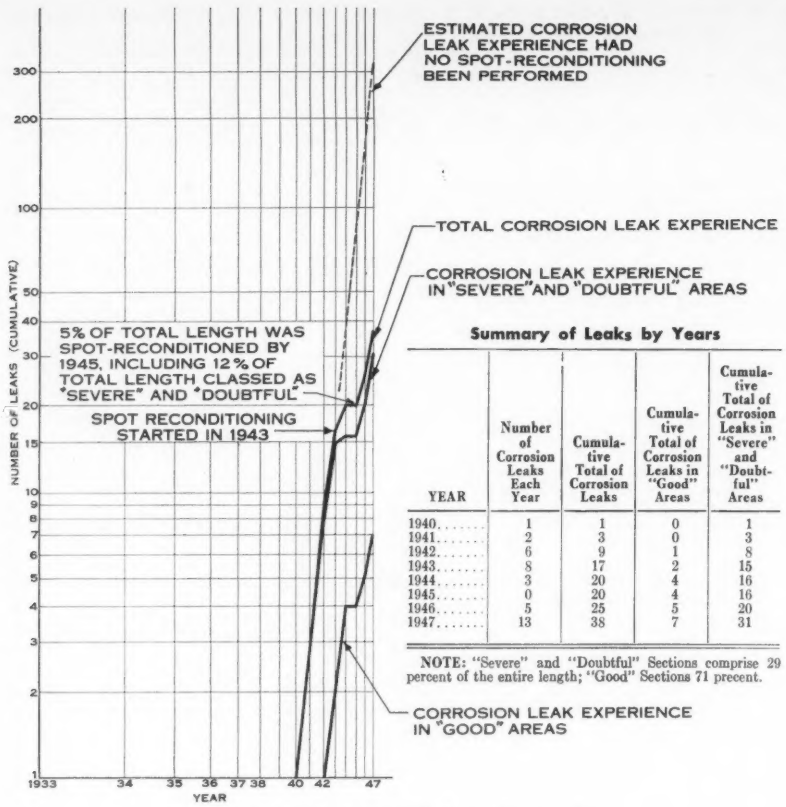
Corrosion Survey Classification and Treatment Afforded Line in Past:	Number of Five-Foot Sections Containing Maximum Pit Depths as Indicated									
	Less Than 100 Mils	100 to 125 Mils	126 to 150 Mils	151 to 175 Mils	176 to 200 Mils	201 to 225 Mils	226 to 250 Mils	251 Mils and Greater	Total	Percent of Length
SEVERE										
Original Surface, Untouched	337	7	4	4	0	0	0	1	353	1.4
Original Surface, within Spot-Reconditioned and Coated Sections	464	41	43	17	9	3	3	1	581	2.3
Added Surfaces, within Spot-Reconditioned and Coated Sections	186	22	34	15	52	17	21	17	364	1.4
Total	987	70	81	36	61	20	24	19	1,298	5.1
DOUBTFUL										
Original Surface, Untouched	1,037	2	1	1	0	0	0	0	1,041	4.1
Original Surface within Spot-Reconditioned and Coated Sections	591	14	9	8	7	3	0	1	633	2.5
Added Surfaces, within Spot-Reconditioned and Coated Sections	81	24	21	1	4	0	0	0	131	0.5
Total	1,709	40	31	10	11	3	0	1	1,805	7.1
GOOD										
Original Surface, Untouched	21,515	40	24	7	3	3	0	1	21,593	84.6
Original Surface, within Spot-Reconditioned and Coated Sections	755	12	6	4	2	0	0	0	779	3.0
Added Surfaces, within Spot-Reconditioned and Coated Sections	54	2	2	0	0	1	0	0	59	0.2
Total	22,324	54	32	11	5	4	0	1	22,431	87.8

TABLE III, SECTION B—Summary of Maximum Pit Depths by Five-Foot Sections, vs. Corrosion Survey Classification and Treatment Previously Afforded the Line

Corrosion Survey Classification and Treatment Afforded Line in Past:	Number of Five-Foot Sections Containing Maximum Pit Depths as Indicated									
	Less Than 100 Mils	100 to 125 Mils	126 to 150 Mils	151 to 175 Mils	176 to 200 Mils	201 to 225 Mils	226 to 250 Mils	251 Mils and Greater	Total	Percent of Length
SEVERE										
Original Surface, Untouched	1,263	33	39	8	2	0	0	1	1,346	2.4
Original Surface, within Spot-Rrcondi-tioned and Coated Sections	708	16	33	30	32	5	1	1	826	1.5
Added Surfaces, within Spot-Reconditioned and Coated Sections	295	29	40	11	18	12	30	52	487	0.9
Total	2,266	78	112	49	52	17	31	54	2,659	4.8
DOUBTFUL										
Original Surface, Untouched	2,039	58	81	42	21	4	2	0	2,247	4.1
Original Surface, within Spot-Reconditioned and Coated Sections	660	31	41	46	33	4	5	2	822	1.5
Added Surfaces, within Spot-Reconditioned and Coated Sections	206	16	10	12	26	7	11	18	306	0.6
Total	2,905	105	132	100	80	15	18	20	3,375	6.2
GOOD										
Original Surface, Untouched	46,493	310	341	219	106	11	5	8	47,493	86.4
Original Surface, within Spot-Reconditioned and Coated Sections	961	21	21	13	7	2	1	0	1,026	1.9
Added Surfaces, within Spot-Reconditioned and Coated Sections	328	27	22	11	12	2	3	0	406	0.7
Total	47,782	358	384	243	125	16	9	8	48,925	89.0

TABLE IV, SECTION C—Summary of Maximum Pit Depths by Five-Foot Sections, vs. Corrosion Survey Classification and Treatment Previously Afforded the Line

Corrosion Survey Classification and Treatment Afforded Line in Past:	Number of Five-Foot Sections Containing Maximum Pit Depths as Indicated									
	Less Than 100 Mils	100 to 125 Mils	126 to 150 Mils	151 to 175 Mils	176 to 200 Mils	201 to 225 Mils	226 to 250 Mils	251 Mils and Greater	Total	Percent of Length
SEVERE										
Original Surface, Untouched	6,635	272	518	411	387	144	164	167	8,698	16.5
Original Surface, within Spot-Reconditioned and Coated Sections	634	3	13	5	2	2	0	0	659	1.2
Added Surfaces, within Spot-Reconditioned and Coated Sections	32	0	0	0	0	0	0	0	32	0.1
Total	7,301	275	531	416	389	146	164	167	9,389	17.8
DOUBTFUL										
Original Surface, Untouched	7,380	164	263	172	142	41	16	34	8,212	15.5
Original Surface, within Spot-Reconditioned and Coated Sections	383	2	10	13	2	1	3	6	420	0.8
Added Surfaces, within Spot-Reconditioned and Coated Sections	72	2	5	1	0	0	0	0	80	0.2
Total	7,835	168	278	186	144	42	19	40	8,712	16.5
GOOD										
Original Surface, Untouched	31,586	474	723	517	455	136	104	114	34,109	64.6
Original Surface, within Spot-Reconditioned and Coated Sections	590	4	0	1	2	0	0	1	598	1.1
Added Surfaces, within Spot-Reconditioned and Coated Sections	8	6	8	0	0	0	0	0	22	0.0
Total	32,184	484	731	518	457	136	104	115	34,729	65.7



Summary of Leaks by Years

YEAR	Number of Corrosion Leaks Each Year	Cumulative Total of Corrosion Leaks	Cumulative Total of Corrosion Leaks in "Good" Areas	Cumulative Total of Corrosion Leaks in "Severe" and "Doubtful" Areas
1940	1	1	0	1
1941	2	3	0	3
1942	6	9	1	8
1943	8	17	2	15
1944	3	20	4	16
1945	0	20	4	16
1946	5	25	5	20
1947	13	38	7	31

NOTE: "Severe" and "Doubtful" Sections comprise 29 percent of the entire length; "Good" Sections 71 precent.

Figure 5—Section D: Corrosion leak experience vs time.

by classifying 22% of the line length as "severe" or "doubtful," located 87% of the five-foot sections which contained pits 100 mils or greater in depth, and 97% of those which contained pits over 200 mils in depth. This compares with corresponding figures for the detailed survey of 12%, 79% and 93% respectively.

For Section B, the visual survey, by classifying 19% of the total length as "severe" or "doubtful," located 40% of the five-foot sections which contained pits 100 mils or greater in depth, and 50% of those which contained pits over 200 mils in depth. These compare with corresponding figures for the detailed survey of 11%, 43% and 82% respectively.

General

Attempts were made to improve the accuracy of corrosion surveys by comparing past corrosion survey measurements with actual pipe condition. While this study afforded explanations for certain specific cases, it was found that they would not hold true in others. Results of this survey have therefore not helped to improve the accuracy of corrosion surveys.

In certain areas corrosion surveys have been repeated over a portion of line. Invariably, the second survey indicated that new corrosive areas have been formed; this is especially true after a spot-reconditioning program has been followed. This might afford an explanation for some of the deep pitting in "good" areas.

Conclusions

1. Corrosion surveys were found to be accurate to the following extent:
   a. Correcting for the effect of spot-reconditioning (i.e.,using the extensions of the curves which appear in Figures 2-5 inclusive) it is estimated that by classifying 21% of the length as "severe," 93% of the corrosion leaks can be predetermined.
   b. Making no correction for the effect of spot-reconditioning (i.e., using the data obtained without modification).
      1) By classifying 21% of the length as "severe" or "doubtful," 67% of the leaks can be predetermined.
      2) By classifying 21% of the length as "severe" or "doubtful," 65% of the bad pipe based on 200 mil depth (or 50% based on 100 mil pit depth) can be predetermined.
2. Spot-reconditioning in accordance with corrosion survey recommendations is not effective for any long period without supplementary cathodic protection.
3. The accuracy of corrosion surveys cannot be improved as a result of this survey.

DISCUSSION

Questions by R. J. Emerson, El Paso Natural Gas Co., El Paso, Texas:

"Did you notice a sudden increase in the number of leaks shortly after reconditioning? My question

TABLE V, SECTION D—Summary of Maximum Pit Depths by Five-Foot Sections, vs. Corrosion Survey Classification

Corrosion Survey Classification	Number of Five-Foot Sections Containing Maximum Pit Depths as Indicated								Total	Percent of Length
	Less Than 100 Mils	100 to 125 Mils	126 to 150 Mils	151 to 175 Mils	176 to 200 Mils	201 to 225 Mils	226 to 250 Mils	251 Mils and Greater		
SEVERE	50	36	93	115	125	93	75	210	797	13.1
DOUBTFUL	215	151	187	166	119	71	42	44	995	16.3
GOOD	2,256	525	506	427	252	146	78	116	4,306	70.6
Total	2,521	712	786	708	496	310	195	370	6,098	100.0

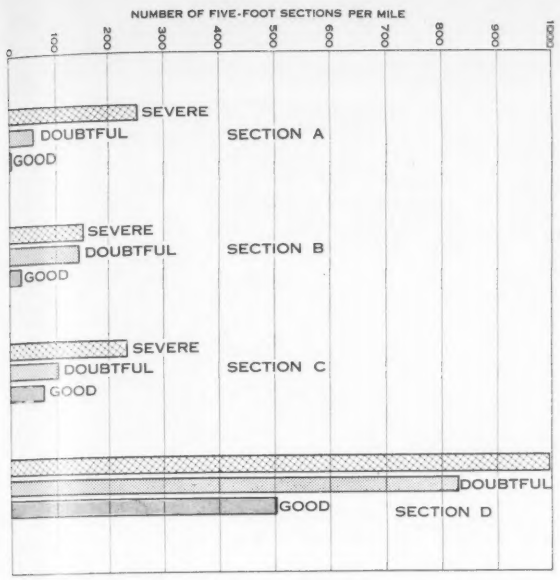


Figure 6—Number of 5-foot sections per mile containing pits in excess of 100 mils in depth.

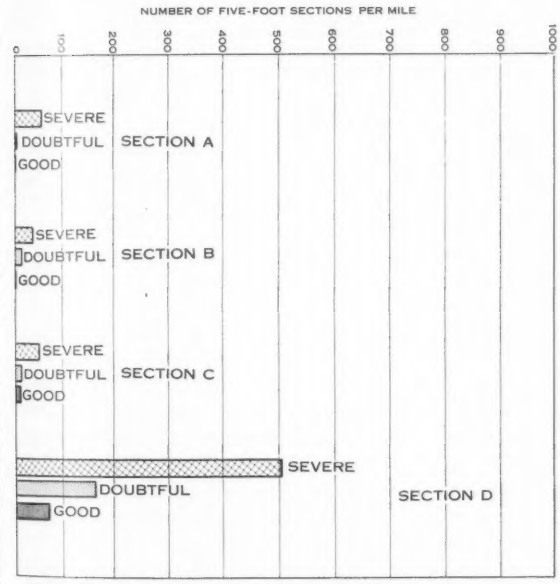


Figure 7—Number of 5-foot sections per mile containing pits in excess of 200 mils in depth.

stems from my company's experience in reconditioning a section of 10-inch line which had been subject to active pitting. Within two months after reconditioning twelve leaks occurred. They all proved to be old pits which had been missed during the reconditioning, mainly because the pipe was not turned bottom side (where most of the pits occurred) up for better inspection. In other words our trouble was poor pipe reconditioning and I wondered if the author had experienced a similar difficulty.

Author's Reply:

No. A sharp decrease was experienced. To date (August, 1949) we have experienced five leaks in the entire 132 miles since the reconditioning. One of the five leaks was at a point where a single deep pit had been located and recommended for repair, but where a spot weld or a patch had not been applied. This is the only leak which has occurred since reconditioning on the 82 miles of line which comprises Sections A, B and D. Cathodic protection was applied to these three sections immediately after completion of the continuous reconditioning. The other four leaks, all of which occurred on Section C, were a result of faulty welding in application of patches over previous leak spots. Each of these was a pin-hole leak in a weld. Cathodic protection is contemplated for this 50-mile section of line in the near future.

TABLE VI
Correlation Between Deep Pitting and Corrosion Survey Classification

Corrosion Survey Classification	Percent of Total Length of Calssification	Percent of Total Number of Five-Foot Sections Containing Pits in Excess of 100 Mils in Depth, Within Classifications	Percent of Total Number of Five-Foot Sections Containing Pits in Excess of 200 Mils in Depth, Within Classifications
SECTION A			
Severe	5	60	87
Doubtful	7	19	6
Good	88	21	7
SECTION B			
Severe	5	20	54
Doubtful	6	23	28
Good	89	57	18
SECTION C			
Severe	18	38	51
Doubtful	16	16	11
Good	66	46	38
SECTION D			
Severe	13	21	43
Doubtful	16	22	18
Good	71	57	39
TOTAL			
Severe	10	31	50
Doubtful	11	19	15
Good	79	50	35

Question by J. C. Stirling, Stanolind Pipe Line Co., Tulsa, Oklahoma:

Is spot reconditioning good?

Author's Reply:

As indicated in Figures 2 through 5, spot reconditioning materially reduced the leak rate; however, Tables II through IV illustrate that most of the deep pitting found during continuous reconditioning occurred in previously spot reconditioned areas.

Our general practice at present is to install cathodic protection at the "hot-spots" on our bare or spot-coated lines, and to employ spot reconditioning only where we feel the pipe is structurally weak as a result of corrosion. Cathodic protection is applied on these spot-reconditioned portions.

The best answer to this question, I believe, is to be found in the conclusion of the paper: "Spot-reconditioning . . . is not effective for any long period of time without supplemental cathodic protection."

Topic of the Month

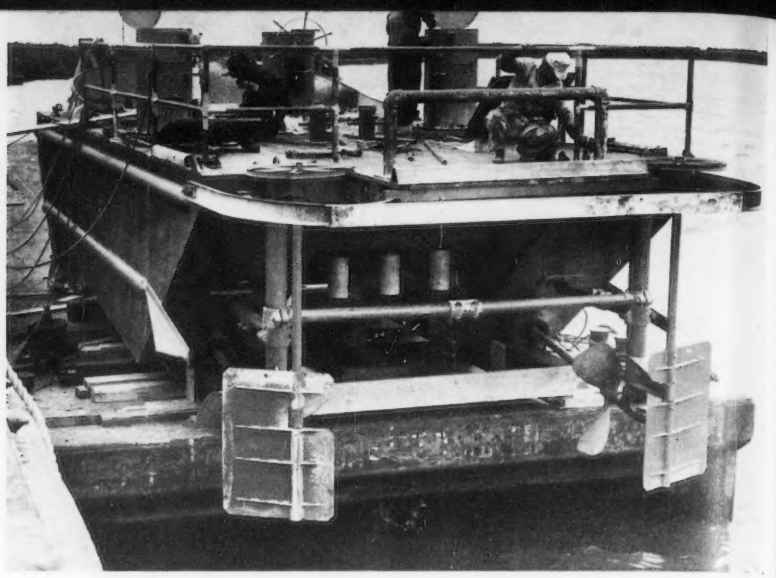


Figure 1—Magnesium anode installation on "Sea Mule" prior to launching.

Cathodic Protection of Marine Tractor

*By OLIVER OSBORN**

THE PROBLEM of hull corrosion on steel vessels operating in sea water has always been a major one. The best known procedure has been to apply paint coatings; however, this remedy has not been altogether satisfactory due to the infrequent intervals at which a ship may be dry-docked for painting and to the difficulty encountered in obtaining paint adherence.

In recent months, work has been directed toward providing a more effective solution to the problem through the use of supplementary protection supplied by galvanic magnesium anodes.

The equipment on which experimentation was conducted was a Chrysler Marine Tractor (Sea Mule) operating in the sea water of the Freeport harbor. This equipment could be dry-docked at convenient intervals for inspection and its construction was such that magnesium anode attachments could be made readily to the hull as shown by Figure 1.

Underwater surface protection consisted of three coats of a vinyl-type paint followed by a vinyl antifouling top coat. Six 50-pound high purity magnesium alloy anodes then were installed in the tunnel section under the deck. Attachment of the anodes was accomplished by welding extension rods to the ends of the ⅜-inch pipe which runs through a standard 50-pound sea water anode, and then bolting these rods to angle iron cross braces.

Four days after the launching of the "Mule," a potential survey was made with a special Cu-$CuSO_4$ reference electrode and it was found that no point on the hull was below a potential of 1.0 volt, which indicated that the underwater surfaces were under effective protection.

The Sea Mule operated in the Freeport harbor for five months and was then dry-docked for inspection. Observations indicated that highly satisfactory results were being obtained, because there was no significant blistering of the anti-fouling paint and the coating breaks caused from abrasion showed no signs of corrosion. Figure 2 shows that a protective calcareous coating was laid down on the unpainted channel sections which support the anodes. It is also possible to see that a protective coating was formed on the hull where the original paint film was injured in welding on the channel sections.

From visual inspection of the anodes, it is estimated that the life of the installation will be approximately one and one-half years. Using the estimated quantity of metal expended as a basis, it is calculated that the average over-all current density applied was 12.8 ma./sq.ft. As indicated by a minimum Cu-$CuSO_4$ potential reading of 1.2 volts taken after three months of operation, the above current density is considerably in excess of the amount actually required for effective protection.

The success of this installation suggests a new and better line of attack for combatting corrosion on the underwater surfaces of marine equipment.

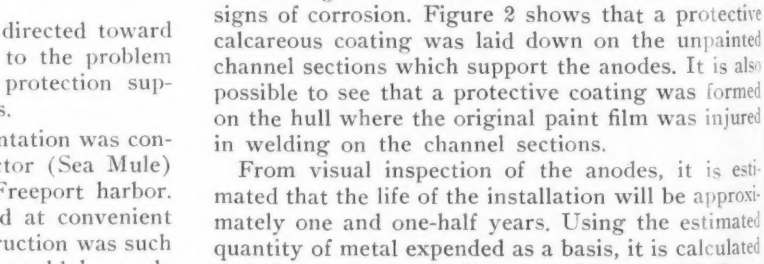


Figure 2—Installation after five months' operation.

* The Dow Chemical Co., Freeport, Texas.

Marine Boiler Deterioration ★

By I. G. SLATER* and N. L. PARR**

Abstract

A survey is made of the several forms of boiler corrosion and deterioration encountered in marine practice. Problems of design, operation and maintenance at sea are discussed in relation to metallurgical and electro-chemical phenomena involved. As regards water-side corrosion, pitting is more frequnetly encountered; general wastage, corrosion fatigue, strain age embrittlement, and caustic embrittlement are in decreasing order of importance. Other forms of deterioration include high-temperature oxidation, bursts, high-temperature creep, and corrosion on the fire side. Several forms of each of the phenomena are illustrated and basic principles involved are discussed.

Introduction

DURING THE 1939-45 war, a full opportunity was made available to study instances of boiler corrosion and deterioration which occurred in His Majesty's ships while they operated under adverse conditions. In marine boilers, adverse factors seldom encountered in normal land practice are commonplace. The sea permeates relentlessly every nook and cranny inboard. To maintain the purity of boiler feed water is a difficult task, and it is to the credit of the marine engineer that the troubles of boiler operation and maintenance have been so far overcome. In addition, circumstances have dictated the rapid adoption of many new modifications and designs in boilers, most often with the view to increasing performance per unit weight, to improve flexibility and to economize in ship's space.

Forms of corrosion and deterioration which may be encountered in marine boilers of both water-tube and fire-tube types have been classified. Table 1 gives this classification, with a key to photographic illustrations of each form of corrosion or deterioration, and also describes their respective characteristics and causes.

The sections which follow discuss in appropriate detail each of the types of corrosion and deterioration noted, and outline certain experimental evidence which has been accumulated in an attempt to elucidate the more fundamental factors involved. An Admiralty pattern boiler is shown in Figure 1. Published work in the field of corrosion has been freely drawn upon in describing the various phenomena involved, and the authors are particularly indebted to the monumental contributions of Dr. U. R. Evans and his associates at Cambridge University (see Bibliography).

Pitting

Pitting is by far the worst type of corrosion encountered on the water side of marine boilers, both for the frequency of its occurrence and its intensely localized nature. Such corrosion occurs mainly in boiler water which has a *p*H (hydrogen ion concentration) value between 6 and 9 and which contains dissolved oxygen and salts.

A broad assessment of the rate and nature of corrosion occurring under boiler operating conditions on steel surfaces when in contact with boiler water over a range of *p*H values is shown in Figure 2, from which it can be seen that isolated pitting may be anticipated even in waters with a *p*H value of 9·4. Pitting is also the main form of corrosion in slightly acid water, but the pits become more and more profuse with increasing acidity until they gradually merge, as general wastage.

The initiation and development of a pit on steel surfaces when in contact with boiler waters (in the range slightly acid to slightly alkaline) is directly associated with the instability of surface films. These films comprise a semi-porous cap of corrosion products which forms over areas being attacked, and which permits the free passage of ions but restricts the ingress of oxygen. Such corrosion can be described as a stage midway between general attack in acid waters and complete inhibition. It develops as a result of electrochemical action involving a difference in potential between existing surface films and patches of bare exposed metal, with sacrificial anodic attack of the latter. The rate of corrosive attack is proportional to the magnitude of current which flows, which in turn depends upon relative surface area of the anode and cathode, nature of the electrolyte, temperature, rate of supply of depolarizing oxygen, and other factors. The characteristics of established pits, such as position, rate of development, nature and appearance of corrosion products, etc., depend upon the conditions existing in the various sections of a boiler, and the main types encountered in marine boilers may be classified under three headings:—

"Air bubble" pitting, which is that associated with oxygen bubbles adhering to the metal surfaces under stagnant conditions.

"Scab" pitting, which occurs in the hotter areas of generating surfaces, and is always associated with hard caps of corrosion products which have been described as "scabs".

"Soft scab" pitting in which the cap of corrosion products is somewhat softer and redder in nature. This type of pitting occurs mainly in drums, superheater tubes, headers, main steam pipes and on any such surfaces which are not submerged in water during idle periods.

Air Bubble Pitting. During idle periods when the boiler stands filled or partially filled with cold water,

★ Paper read at an extra general meeting of the Institution of Mechanical Engineers, in association with the Steam Group, February 4, 1949. Published, **Proc. Inst. Mech. Eng.**, 1949. Permission to reprint in CORROSION granted by Dr. I. G. Slater.

* Director of operational research, Admiralty.
** Senior scientific officer, Royal Naval Scientific Service.

a substantial amount of air may find its way into the water. Solubility decreases rapidly with rise in temperature, and thus, consequent on small daily fluctuations in room temperature, conditions may result in air being thrown out of solution to collect as bubbles on the metal surface. These bubbles attach themselves to the adjacent metal surfaces throughout the entire boiler below the water level. At some areas, such as the roofs of water drums, etc., there may be a greater concentration of bubbles than elsewhere. Furthermore, when prolonged non-steaming periods are anticipated, it is the general practice to fill the idle boiler completely with water, and this extends the surfaces liable to suffer from this form of deterio-

TABLE I—Forms of Boiler Deterioration

CLASSIFICATION	Appearance of Corrosion	Usual Location	Cause	Fig. No.
Boiler Deterioration — Internal Deterioration — Pitting — Air bubble pitting	Isolated hemispherical pits, often covered with a cap of loose soft corrosion products, which when dry is of black iron oxide covered with a membrane of red dehydrated ferric hydroxide.	Mainly on the roof of steam and water drums, but likely to be found on any surfaces in contact with water, where air bubbles may collect.	Liberated air bubbles attaching themselves to metal surfaces, thereby initiating anodic attack by the generation of localized electrolytic action.	3 4
Boiler Deterioration — Internal Deterioration — Pitting — Scab pitting	Deep localized pitting covered by a scab of hard scaly black magnetic iron oxide which cannot be removed by wire brushes.	In hotter areas of heating surfaces where corrosion products are formed and rapidly consolidated into a hard scab by the heat. This is possibly the main form of deterioration encountered.	Use of untreated impure boiler water containing dissolved salts and gases in comparatively small concentrations so that pH of water lies between 4·4 and 9·4.	6 50 7 51
Boiler Deterioration — Internal Deterioration — Pitting — Soft scab pitting	Broad, shallow pitting covered with caps of fairly hard corrosion products, usually black magnetic iron oxide covered with a layer of red dehydrated ferric hydroxide.	In superheater tubes and headers and in main steam lines.	Deposits of salts by priming in superheaters, main steam lines, etc., followed by condensation when the boiler is shut down, resulting in the formation of droplets of electrolyte and the initiation of a pit by differential aeration.	9 10
Boiler Deterioration — Internal Deterioration — General Wastage — Tube wall thinning	A general reduction in tube wall thickness over comparatively large areas, often without the presence of blankets of corrosion products.	Fairly evenly distributed over water surfaces with a tendency to be more pronounced in hotter areas.	Use of acid feed water.	12 13 14
Boiler Deterioration — Internal Deterioration — General Wastage — Necking and grooving	A circumferential band of corrosion on the water-side of fire tubes, stay tubes, and stay bolts in Scotch boilers.	Where stay bolts, stay tubes, and fire tubes enter end plates or combustion chambers.	The influence of adjacent end plates on expansion and contraction, resulting in stresses which cause repeated localized flaking of protective films.	15 16
Boiler Deterioration — Internal Deterioration — General Wastage — Galvanic attack	Local reduction in metal thickness.	Adjacent to non-ferrous boiler mountings, in areas of non-homogeneity of steel composition or at breaks in surface films.	Use of dissimilar metals in contact (or at areas of non-uniformity on the metal surfaces) in the presence of an electrolyte, when a difference in potential will result in sacrificial electrolytic attack at the anode.	17 53
Boiler Deterioration — Internal Deterioration — Corrosion Fatigue — In tubes	Network or series of cracks over the water-side of tube surfaces.	In boiler and superheater tubes on the hottest side of the bores. It is most frequently found in inherently curved tubes or tubes which have been buckled in service.	Irregular circulation in tubes causing frequencies of alternate overheating and cooling which induce pulsating thermal fatigue stresses in the walls. Cracking is accelerated by residual stresses and a corrosive environment.	19 20 21
Boiler Deterioration — Internal Deterioration — Corrosion Fatigue — In steam and water drums	Fissures, usually difficult to detect due to covering layers of corrosion products; usually associated with deep pitting.	Commencing at the arbouring in tube, plates and extending axially, eventually joining two or more holes.	Bending stresses due to lack of common neutral axis between tube and wrapper plate, and excessive cold working due to initial rough machining operation. Accelerated by thermal stress and corrosive environment.	22 23
Boiler Deterioration — Internal Deterioration — Corrosion Fatigue — In main steam pipes	Lines of cracks on bores of pipes.	On the bores of main steam pipes, especially in the base or corrugations.	Bending stresses due to movement during operation in the presence of a corrosive environment.	24
Boiler Deterioration — Internal Deterioration — Strain age embrittlement	Spontaneous cracking in boiler components during detubing or cleaning operations.	Between tube holes in tube plate, under rivet heads, round top end of tubes adjacent to the rolling surfaces.	Reduction of impact properties by the combination of cold work and ageing. Spontaneous failure occurs only at and below room temperature.	25
Boiler Deterioration — Internal Deterioration — Caustic embrittlement	Fissures in boiler plates, etc.	In boiler plates, radiating from and often connecting adjacent rivet holes, joints, arbourings, etc.	Joint effect of a combination of non-uniform stressing, and high concentration of caustic soda in the presence of a catalyst at high temperatures.	26
Boiler Deterioration — Internal Deterioration — Deterioration at Elevated Temperatures — High temperature oxidation	Continuous layers of hard black magnetic iron oxide scale.	Internal—in fire row and superheater tubes; occurring in drums and headers. External—on surfaces in contact with furnace gases.	Internal—poor circulation resulting in overheating in a steam atmosphere. External—local flame impingement or poor circulation or presence of heat insulating scale on water side.	32 33
Boiler Deterioration — Internal Deterioration — Deterioration at Elevated Temperatures — Bursts	Longitudinal gaping split which may or may not be associated with ballooning.	Hottest side of generator or superheater tubes.	Water starvation, resulting in overheating with corresponding reduction in mechanical properties of the tube until bursting occurs under working pressure.	34 35
Boiler Deterioration — External Deterioration — High temperature Creep cracking	Cracking and splitting associated with layers of high temperature oxide scale on tube surfaces.	In superheater tubes.	A combination of stress due to restricted expansion and overheating at temperatures around 550 deg. C.	36 37
Boiler Deterioration — External Deterioration — General wastage by damp soot	Localized wasting of boiler metal which can only be seen after removal of soot deposits.	Wherever soot collects, especially where tubes enter lower drums and headers.	Presence of sulphuric acid formed by action of moisture (when shut down) on oxides of sulphur present in the oil fuel soot.	28 29

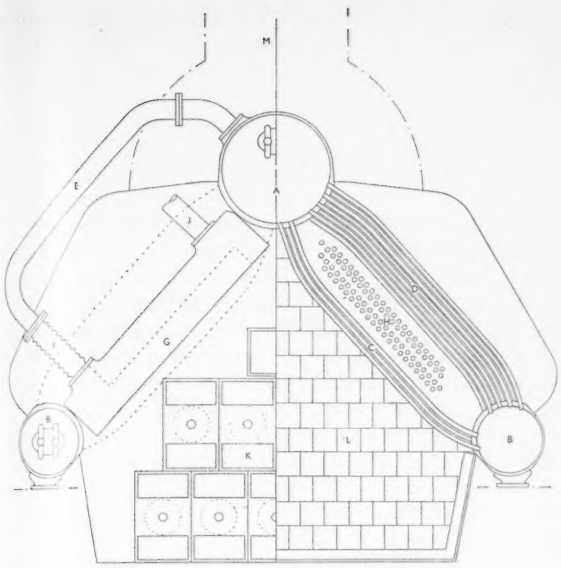


Figure 1—Marine water-tube boiler, Admiralty Yarrow type.

A—Steam drum
B—Water drums
C—Generator tubes
D—Downcomers
E—Saturated steam pipe
F—Corrugated expansion pipe
G—Superheater header
H—Superheater tubes
J—Main steam line
K—Oil burners
L—Furnace
M—Uptake

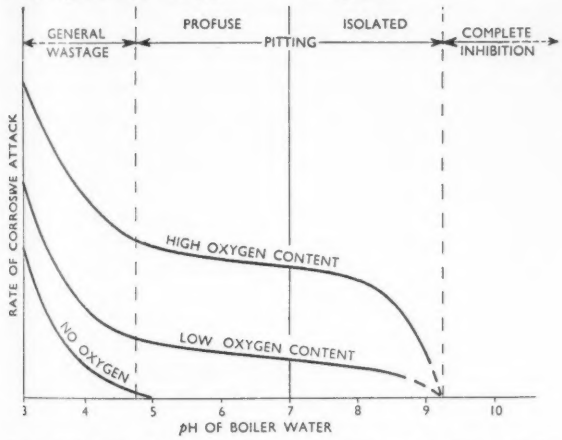


Figure 2—Relationship between corrosion of steel and conditon of boiler water.

ration. Typical examples of air bubble pitting existing on a range of water surfaces are given in Figures 3 and 4.

Where such bubble attachment has occurred, a potential difference will exist on the metal surface between the oxygen rich areas under the bubble and the surrounding areas in contact with water which will be less rich in oxygen. As a result of the electric current which then flows, a ring of corrosion will occur in the areas lower in oxygen content (anodic areas) surrounding the bubble. Corrosion products which form tend to build up over the surfaces of the bubble by capillary attraction, thus completely isolating it from the surrounding water. A diagrammatical representation of the initial and final stages in the development of this type of corrosion pitting is outlined in Figure 5.

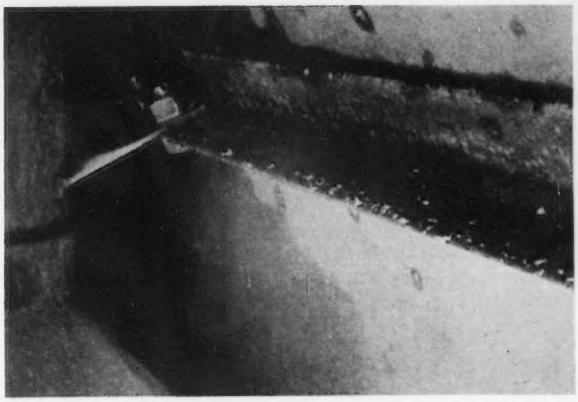
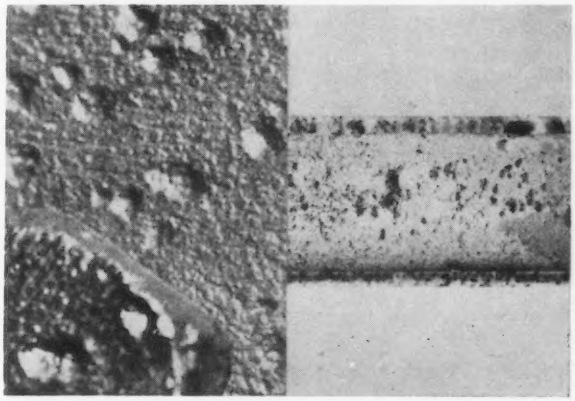


Figure 3—Soft caps of red iron oxide surmounting "air bubble" pitting on internal fittings in a steam drum.



(a) (b)

Figure 4—The result of "air bubble" pitting on a) the roof of the steam drum, b) the bore of a tube.

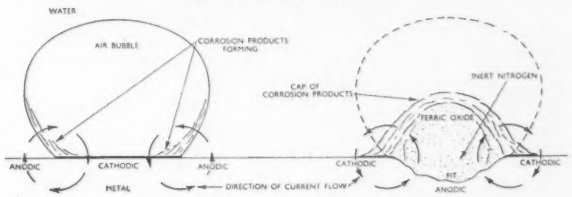


Figure 5—Two stages in the formation of an air bubble pit.

As the electrolytic reaction proceeds and the cap of corrosion product around the bubble thickens, oxygen inside the bubble is used up in converting the corrosion products into their fully oxidized state, leaving inert nitrogen inside the developing pit. Thus a stage is finally reached where the entire amount of oxygen under the cap of corrosion products is used up. The polarity of the small electric cell is then reversed, the area around the bubble becoming cathodic and that beneath the bubble anodic, corrosive attack proceeding below the cap as long as it remains intact. This cap of corrosion products has to be sufficiently porous to allow the passage of ions, but oxygen impoverishment exists below, owing to the immediate utilization of any ingressing oxygen in oxidizing corrosion products immediately under the cap. Thus once a bubble of oxygen has attached itself to the

metal surface, corrosion will be initiated and will proceed irrespective of any subsequent changes, until the boiler is emptied and dried, causing the collapse of the cap of corrosion products, which will be found to consist of an outer layer of soft red iron oxide (Fe_2O_3), with an inner core of powdery, black magnetic iron oxide (ferroso-ferric oxide, Fe_3O_4) which fills the pit.

This form of deterioration is not so serious when it occurs on drums, owing to the thickness of metal and accessibility for cleaning. Where, however, it occurs on boiler tubes, it may be very serious and has been known to constitute up to 30 per cent penetration in one stagnant period of two weeks duration. Moreover, it may initiate scab pitting on generator tubes if subsequent boiler water treatment is not employed. In some cases, examination suggests that the corrosion nodule is broken up by turbulence during subsequent steaming periods. Observations suggest that corrosion need not necessarily recommence over an existing broken nodule, but if possible it is best to brush away such corrosion products before refilling the boiler. The application of a layer of graphite on the drums appears to assist in immunizing from this form of attack, but this procedure is not to be advised on surfaces transmitting heat at higher rates owing to the possibility of localized breakdown with subsequent concentrated attack at the bare steel thus exposed. The only way to ensure complete freedom from this form of deterioration apart from completely emptying the plant and keeping it dry with the aid of heaters or dehumidifiers, is to exclude all oxygen from stagnant boilers. This may be achieved by adding a small amount of sodium sulphite (which will react with the remaining free oxygen) to the boiler water which is already treated with boiler compound.

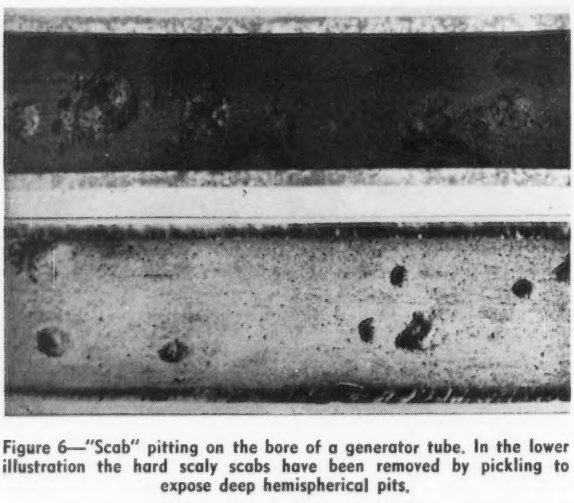


Figure 6—"Scab" pitting on the bore of a generator tube. In the lower illustration the hard scaly scabs have been removed by pickling to expose deep hemispherical pits.

Figure 7—Massive "scab" pitting on the water side of a fire tube.

"Scab" Pitting. A more virulent type of pitting may occur on the hotter areas of generating surfaces such as the hotter side of fire row tubes in a water-tube boiler. A hard, firmly adhering, bluish-black, scaly scab of corrosion products is formed over the developing pit, which, once formed, may rapidly lead to complete penetration of the tube wall. Examples of this form of deterioration are given in Figures 6 and 7. A typical scab removed intact from a boiler tube is shown in Figure 30, and comprises layers of hard, black, magnetic iron oxide in contact with the base of the pit, surmounted with a cap of red iron oxide which exudes beads of ferric chloride when dry.

The mechanism, and the precise conditions suitable for the initiation, of scab pitting are not, as yet, clearly understood. Initiation of this attack may involve oxygen bubbles, non-homogeneity of boiler tube steels, cracks in the oxide scale, or stress concentrations, but localized breakdown of semi-stable protective surface films is undoubtedly the predominating cause, which has already been shown to be a

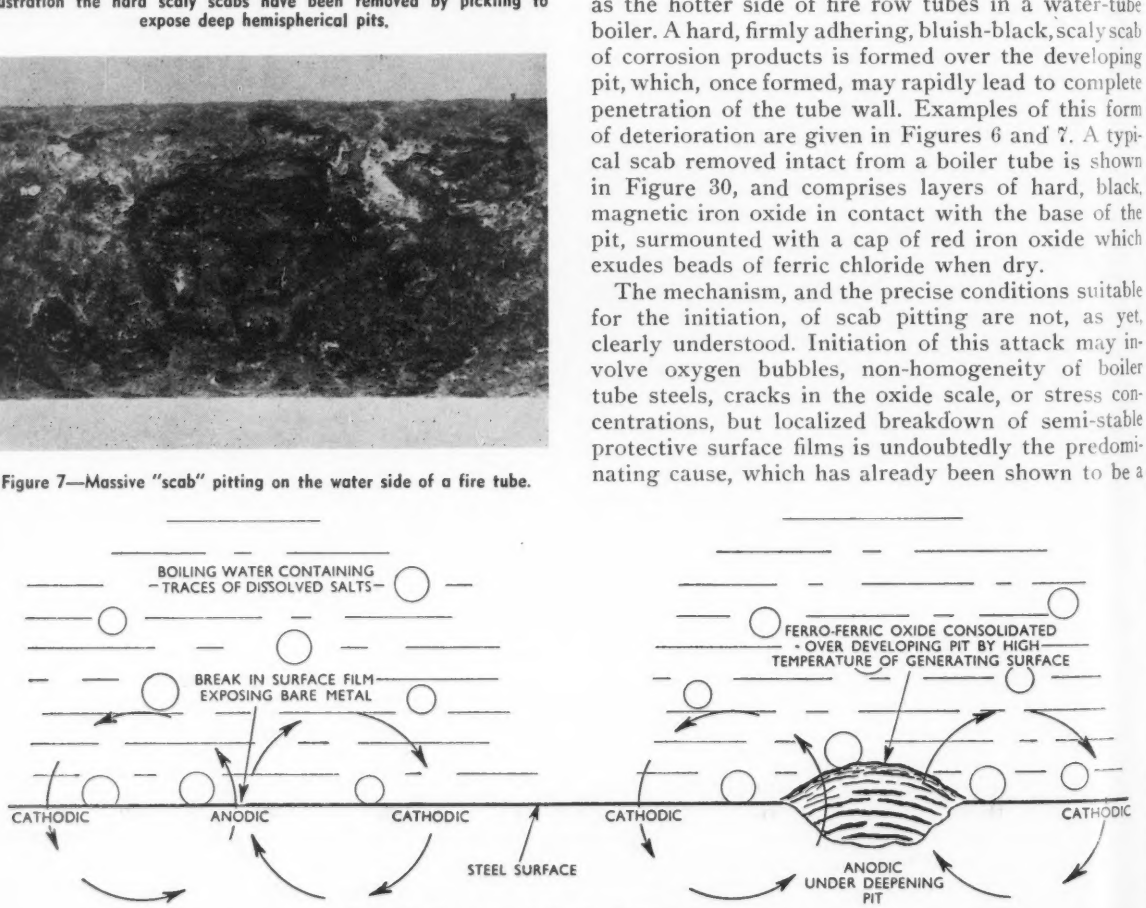


Figure 8—Two stages in the development of a scab pit.

Figure 9—Large "soft scab" pits on the bore of a superheater tube.

Figure 10—Profuse "soft scab" pitting on the bore of a superheater tube.

function of the composition of the boiler water. It has already been shown that below *p*H 6, protective films are completely unstable, and between *p*H 6 and 9.6 they are only partially stable, and it is in waters coming in this latter category that this form of deterioration most frequently presents itself. Scab pitting is also invariably associated with the use of boiler water contaminated with moderate amounts of dissolved salts, e.g. up to 140 parts per million, which hinder the formation of stable protective films and which greatly increase the conductivity of the water as an electrolyte. In marine practice, such contamination is due to chlorides from the sea-water which has found its way into the feed water, but similar scabbing has been noted in land practice as a result of contamination by other salts such as sulphates.

A probable mechanism of scab pitting involves the initiation of anodic attack on the metal surfaces by one of the factors noted above, which will then proceed favorably in the presence of the salt-contaminated boiler water. This is illustrated diagramatically in Figure 8. As the pit develops under the anodic surface, alkali is formed at the cathode (i.e. in areas surrounding the pit) as a result of the accumulation of hydroxyl (OH) ions. This alkali will tend to stabilize oxide films surrounding the pit, and by spreading laterally may stifle attack at any other incipient anodic point in the vicinity. Thus the distribution of centers of initial attack may tend to alter with time, some persisting, and others disappearing, until the position is more or less stabilized, and well defined pits are established. Where the boiler water contains significant traces of sea-water, both the anodic and cathodic products of electrolysis, ferrous chloride and sodium hydroxide respectively, are soluble, and will react to form an insoluble cap of ferrous hydroxide over the point of attack—a product identical with that noted in air bubble pitting. As hard scab pitting is always confined to areas of high heat transfer, it is evident that the hotter conditions prevailing cause the cap of corrosion products to compact and harden. The electrolytic cell set up under the scab will proceed to function so long as oxygen is available in the boiler water to depolarize the hydrogen diffusing outwards through the scab. As the scab thickens and hardens, so the pits become more established and localized, and more tenacious to the tube walls. The rate of attack may be increased with the higher temperatures involved, since the conductivity of the electrolyte increases with temperature. The result is an ever-deepening pit which has a non-selective penetration into the structure of the metal, as illustrated in Figure 38. It is always filled with compacted layers of iron compounds in a reduced state, which are so hard as to defy all mechanical attempts at disruption by normal cleaning methods. Ultimately perforation takes place, either by leakage or splitting across the base of the pits as illustrated in Figures 50 and 51.

It is conceivable that, in addition to the anodic attack, acid corrosion of the hydrogen evolution type may proceed under the scab, as a result of the formation of free hydrogen chloride by decomposition of any entrapped magnesium chloride at temperatures above 180 deg. C. (356 deg. F.).

In order to halt the attack when once started, it is necessary to remove the hard scab of corrosion products to expose bare metal in the pit, and then to reform a protective film over the entire surface. Drying out the boiler may be of some limited value, and some scabs may flake away when tubes are subjected to contraction. The more usual tube cleaning operations, thermal fluctuations with consequent expansion and using power-driven wire brushes, fail to break away many scabs, and the only certain method is by acid pickling. This latter method is, however, fraught with many incidental problems, and if not carried out with laboratory precision may lead to even more virulent corrosive conditions, consequent on only partial removal of corrosion products and incomplete neutralization of residual acid.

Experience has indicated that scab pitting can be initiated during a relatively short period of boiler operation with significantly contaminated feed, and in the absence of a boiler water treatment to give the water a definite degree of residual alkalinity. This attack will continue during subsequent steaming periods even though the degree of contamination is extremely slight. However, by giving the boiler water a definite positive alkalinity and maintaining a *p*H value of 10·0–11·0, corrosive attack is completely inhibited by making surface films both stable and self-healing should rupture occur by mechanical or other means. The nature of such films depends to some extent on the composition of the boiler compound used for the chemical treatment, and are usually a mixture of ferroso-ferric oxide and metallic phosphates. Further, it has been observed that in many instances this treatment modifies the physical nature of the cap of corrosion products, ultimately causing it to disintegrate and fall away. If, when this occurs, the composition of the water is such as to promote the formation of stable protective films, corrosion will cease and complete freedom from it will be obtained.

"Soft Scab" Pitting. The visual appearance of this form of attack, as may be seen in Figures 9 and 10, is reasonably similar to that discussed in the previous

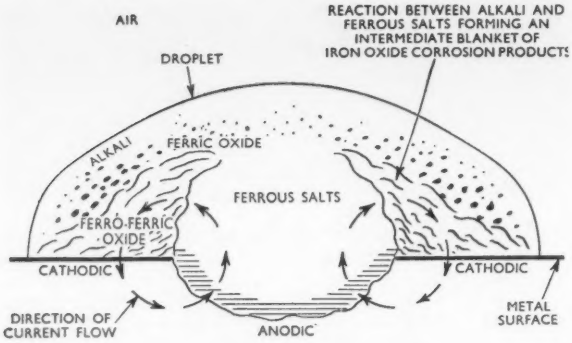


Figure 11—Formation of a soft scab pit.

section, except that the cap of corrosion products is much softer and contains a higher proportion of red iron oxide (Fe_2O_3). It occurs mainly in superheater headers, superheater tubes, main steam piping, and on any steel components above the water line in the boiler liable to come in contact with water which has primed from the boiler.

When such priming occurs (usually as a result of high total dissolved solids in the boiler water), the water deposited will evaporate, leaving salts on the surfaces concerned. Under humid conditions, such as will exist when the boiler is shut down, droplets of condensate may form on these metal surfaces and will then dissolve any salts in their immediate vicinity, producing small droplets of quite concentrated electrolyte. This will give rise to intense local attack at favourably disposed areas, the sequence of development being somewhat similar to that previously discussed. The initial and final stages in the development of a soft scab pit are illustrated diagrammatically in Figure 11, from which it can be seen that electrolytic attack is initiated by a difference in potential between the inside and outside of the droplet consequent on an oxygen content gradient. Subsequently, corrosion products forming at an intermediate position produce a semi-permeable membrane and establish the corrosion cell. Final products of electrolysis comprise black ferroso-ferric oxide (Fe_3O_4) on the inside and fully oxidized ferric oxide (Fe_2O_3) on the outside. Subsequent steaming will dry out moisture from the corrosion cap and further oxidize the iron compounds present to the "red rust" (Fe_2O_3) condition; this is a frequent characteristic observed in superheater tubes where operation has been intermittent.

Once this type of deterioration has been established, it may recontinue whenever the boiler is shut down and condensation takes place. Droplets of salt-contaminated water primed from the boiler may reach areas some distance away, and attack of the type noted has been found on manoeuvring valves, turbine blading, etc. In order to be free from this form of corrosion it is necessary either to fill with correctly treated water components liable to be affected, or, on running down the boiler, to ensure complete dryness by the provision of a form of dehumidification.

General Wastage

General internal wasting describes corrosive attack of a more uniform nature rather than selective local attack by pitting. Reduction in metal thickness occasionally may be evident over comparatively large areas, and the three most common forms of attack are: (1) Thinning of tube walls. (2) Necking and grooving by circumferential bands of wastage around tubes or stays in cylindrical boilers, where they enter boiler plates. (3) Galvanic attack by dissimilar metals in contact or at surface irregularities.

These forms of attack are described and discussed in more detail in the following sections.

Thinning. When untreated boiler water is contaminated with sea-water, it tends to become slightly acid in nature (under boiler operating conditions) possibly as a result of the partial decomposition of the salts present, and in particular of magnesium chloride. Additionally, dissolved carbon dioxide results in acidity. The relationship between the *p*H of water, the oxygen content, and the type and rate of corrosion, has already been discussed, and has been shown diagrammatically in Figure 2, from which it can be seen that below a *p*H value of 5·0, corrosive attack is no longer selective but general.

Such corrosion of steel in acid solutions proceeds in an even and non-selective manner, by virtue of the fact that the resulting corrosion products are soluble, or do not form obstructive or protective films at the metal surface. At *p*H values below 5·0 metal wastage proceeds in the absence of oxygen, and is of the hydrogen evolution type. The rate of attack depends on a number of factors, including the degree of acidity of the water, temperature, and the nature of the surface being attacked. Additionally, it is possible that local isolated pockets of acid water may exist under blankets of corrosion products or deposits as a result of the decomposition of entrapped magnesium chloride, which will then cause localized

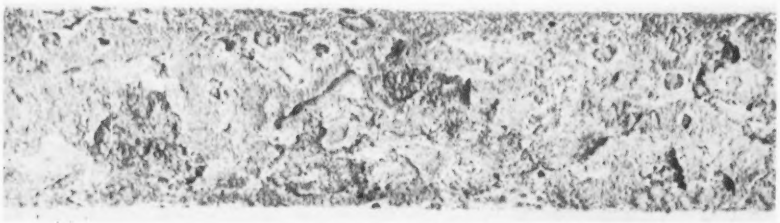


Figure 12—Blanket of soft, loose corrosion products surmounting "general even wastage" of the bore.

Figure 13—Reduction in wall thickness by "general wastage."

acid attack even when the bulk of the boiler water may be neutral or alkaline. The presence of dissolved oxygen in the boiler water increases both the rate and range in which acid corrosion will occur.

Consequent on the sporadic rupture of unstable surface films in water of a *p*H value between 5·0 and 6·0, sites of attack change before any point of anodic attack has proceeded long enough to develop a local pit. As a result of boiler water continually tending to become slightly alkaline by the continuous formation of ferrous hydroxide, conditions liable to result in this form of deterioration are seldom encountered, but on occasions, mainly due to fortuitous sea-water contamination, general even wastage has taken place. Such an example is illustrated in Figures 12 and 13, and an example of this form of deterioration occurring under heavy deposits is given in Figure 14.

Necking and Grooving. This type of corrosion, which is a special case of general wastage, occurs mainly in cylindrical boilers on smoke tubes, combustion chamber stays, or longitudinal stays where they enter boiler end plates. A typical example of necking occurring on a fire tube where it enters the tuble plate is shown in Figure 15. Such wastage is confined to the end adjacent to the tube plates, and is undoubtedly due to the local flaking of protective films. At the tube ends, strains adequate to flake protective films on the tube surface are set up, consequent on expansion and contraction. Thus a circumferential band of bare metal is continually exposed to the boiler water. More or less intermittent attack will proceed at this area as the protective films successively break away, the amount of attack depending upon the relative corrosiveness of the boiler water.

Additional to this continued mechanical exfoliation of films at tube ends, localized corrosion may be observed at areas coincidental with the junction of the tubes and end plates, where millscale on new unpickled tubes has been flaked away by the rolling and expanding operation when tubes were fitted in the boiler. On very rare occasions, attack in the capillary between tubes and rolling surfaces results from the concentration of salts, particularly magnesium chloride, and their subsequent partial decomposition to acid, leading to localized acid corrosion of the hydrogen evolution type. Such a case occurring at the edge of the rolling surface of a generator tube is illustrated in Figure 16, in a water-tube boiler where it emerges into the steam drum.

As with thinning, wastage by "necking" and "grooving" is favoured by the use of acid or nearly neutral boiler water. Such wastage is completely eliminated if the boiler water is given a correct alkalinity by chemical treatment.

Galvanic Attack. Dissimilar metals in contact in the presence of an electrolyte produce a short-circuited cell in which the less noble metal forms the anode, with consequent wastage, and the more noble metal forms the cathode, which is unattacked. The intensity of the attack depends upon the current density at the anode, which is a function of the conductivity of the electrolyte, the sizes of anode and cathode, polarization at the anode and cathode, and the potential difference between the two metals on an open circuit. Conductivity of boiler water is greatly increased by the presence of dissolved salts, and thus this form of deterioration will readily proceed in boiler water containing small quantities of sea-water. If, however, the boiler water is sufficiently alkaline, polarization—particularly at the anode—is greatly increased owing to the formation of stable protective films. The potential difference between various metals on an open circuit varies somewhat with the nature of the electrolyte in which they are immersed. In the case of the usual run of boiler waters, the following metals are set out in the order in which any metal is less noble (anodic) with respect to those which follow it: zinc, wrought iron, steel (cold worked), steel (normalized), brass, copper, gunmetal, monel metal, stainless steel, graphite.

Steel is thus anodic to a number of other nobler metals which may be used for fittings in boilers. In general, however, the area of steel is very large in comparison with that of the fittings, so that the current density at the steel is relatively small. Cases do occur where serious local galvanic attack is encountered, and an example is given in Figure 17, which

Figure 14—"General even wastage" around a tube end under a heavy accumulation of sludge.

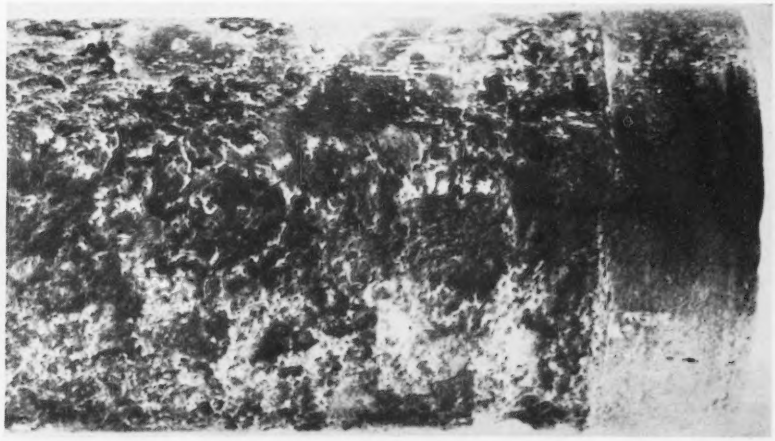


Figure 15—"Necking and grooving" immediately adjacent to where a smoke tube in a cylindrical boiler enters an end plate.

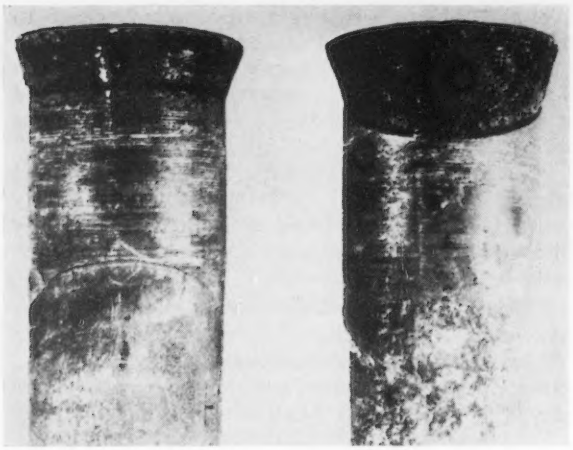


Figure 16—"Grooving" arund water-tube ends where they emerge from the rolling surface into the drum.

Figure 17—"Galvanic attack" on the bore of a mild steel generator tube immediately adjacent to where a stainless steel nozzle had been located in the tube end.

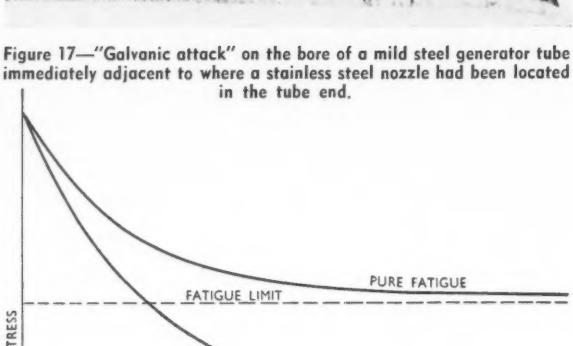


Figure 18—Comparison between fatigue and corrosion-fatigue curves for mild steel.

shows severe wastage in a tube end immediately adjacent to a stainless steel nozzle inserted inside a generator tube of a forced circulation boiler. In this instance, water treatment had been inconsistent, and it is appropriate to mention that subsequent laboratory experiments clearly demonstrated the value of a correctly maintained boiler water in inhibiting this galvanic attack.

Galvanic attack can be used in a broader sense to describe corrosion which will occur by electric currents flowing as a result of irregularities in the metal surface. Perhaps the best illustration of this is when mill-scale existing on the metal surfaces fractures to expose bare metal underneath, the less noble bare

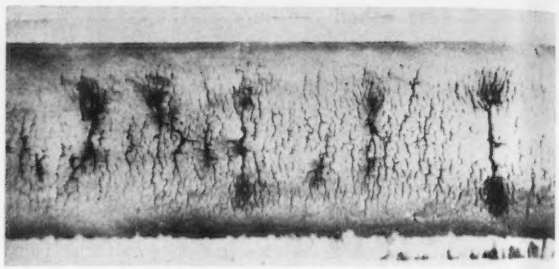


Figure 19—Network of "corrosion fatigue" fissures on the bore of a generator tube. Main fissures are circumferential, in a network of crazy cracking.

steel dissolving, often locally with the formation of a pit. A good example of this is illustrated in Figure 53, which shows lines of corrosion along Luder's lines on a tube wall, where strain has caused a thin surface film of iron oxide to fracture along planes of maximum stress. One particularly large pit has developed at the intersection of two of these lines of exposed metal. Other surface irregularities such as cold work, non-metallic inclusions, grease deposits, etc., each give rise to a potential difference, and the generation of local electrochemical activity with the commencement of this type of corrosive attack.

Cases are on record where galvanic attack on broken millscale surfaces of unpickled fire tubes, fitted in Scotch marine boilers, has proceeded with such rapidity that perforation has taken place in as short a space of time as two weeks. Quite often also, chains of pits have developed along the top surface of smoke tubes, as a result of galvanic attack under a layer of sludge which has been deposited between the tubes in zones where turbulence by steaming is at a minimum.

The principle of galvanic attack has also been used for protecting steel surfaces in boilers by sacrificial attack of less noble metal anodes, usually zinc slabs spaced throughout the boiler, but such protection has been found to be extremely local and it has been abandoned for more positive methods.

The foregoing refers principally to phenomena which take place at atmospheric temperatures and pressures, and hence which may occur when the boiler is cold. The significance of higher temperatures and pressures on galvanic attack are as yet less clearly understood, and it is probable that substantial modifications in the phenomena are involved. For example, it has recently been demonstrated that zinc may become cathodic to steel in certain waters at temperatures above 80 deg. C. (176 deg. F.).

Corrosion Fatigue

The significance of a corrosive environment in substantially modifying the normal fatigue limit of a material in air has been clearly demonstrated by many previous investigators. In a corrosive environment a true fatigue limit is never attained because at any stress, however small, fracture will ultimately occur. For practical purposes, a corrosion fatigue limit may be specified for a definite number of stress applications in a given corrosive environment, and curves expressing the difference between the two phenomena for a range of stresses are given in Figure 18.

Many boiler components are subjected to stress fluctuations during the operation of a boiler. In some cases these fluctuations may be frequent and severe, as in a generator tube where circulation may be defective. In other cases the fluctuations may be relatively infrequent and occur only when the boiler is heated up and cooled down. The influence of a corrosive environment (e.g. untreated boiler water) on the initiation and subsequent propagation of fatigue cracks involves the following possibilities:—

(1) The surface of the metal may be roughened by corrosive attack and so give rise to stress concentration effects which have a significant adverse effect on the fatigue limit.
(2) An extending crack will result in the continued breakdown of protective films at its terminus and thus leave bare metal continuously open to further corrosive attack.
(3) More highly stressed areas are anodic to less highly stressed areas and attack is thus favoured at the former. The terminus of a pit or crack coincides with a stress concentration, and hence maximum corrosive attack is encouraged at such points.

Corrosion fatigue fissures are characterized by the direct path which they take across the crystal structure of the material. They usually take the shortest path through the component being stressed, and show no preference to pass around crystal boundaries. The broadness and shape of the fissures, and the rate of crack propagation, depend up the magnitude and frequency of the stress application and the nature of the corrosive enrironment. For instance, under mildly corrosive conditions but with high frequency and a stress concentration of fair magnitude, fissures may develop as hairline cracks. On the other hand, with a low stress concentration and low frequency, a corrosion fatigue fissure may be so broad and filled with corrosion products that it more resembles a pit. Figures 40 and 41 show typical corrosion fatigue fissures frequently found in boiler tubes, where both the frequency and the magnitude of stress concentration are comparatively high. These can be compared with Figure 39, which shows a corrosion fatigue fissure in a main steam pipe, where the stress frequency has been so small that the deterioration may be more aptly described as stress corrosion, which is a form of preferential corrosive attack encouraged by a potential difference existing between stressed and unstressed areas.

Corrosion Fatigue in Tubes. Corrosion fatigue cracking may be found in almost all boiler components, but is most common in boiler and superheater tubes. In boiler tubes, the stress frequency can be attributed to rapid changes in surface temperature along the bores, as a result of intermittent circulation. The cause of poor circulation in natural circulation boilers is a much discussed phenomenon, and involves correct distribution of heat in the furnace through the tube bank, a complete separation of steam and water in the steam drum, and other factors involving the actual design of the boiler, which are beyond the scope of this paper. Laboratory experiments have shown, however, that intermitten slugs of steam and water, passing along the boiler tube, will result in pulsating thermal skin stresses of sufficient magnitude to result in a network of tiny fatigue cracks developing on the bores.

The rate of propagation of these cracks is usually slow, but where boiler tubes operating under these conditions are under the influence of additional tensile stresses the rate of crack development is correspondingly increased. Thus, tubes which are curved or buckled as a result of local restriction to expansion are the first to exhibit this form of deterioration, as a result of bending moments inducing skin tensile stresses along the bores. For this same reason, failures are often immediately adjacent to rolling surfaces where tube movement has induced tensile stresses of considerable magnitude. This form of deterioration is not entirely confined to generator tubes, as some boiler designs are such that circulation in some of the downcomers (usually the first few rows) is extremely sluggish and may, due to violent changes in steaming rate, result in these latter tubes alternating as risers and downcomers. Examples of the profuse nature of cracking which may be found on generator tubes under these conditions is shown in Figure 19.

The influence exerted by the nature of the generating surface on the production of steam bubbles is well known, and a generating surface corrugated by a large number of tiny cracks offers many nuclei for steam bubble generation. This, together with the large heating surface offered by fissures, may result in violent liberation of steam bubbles, which will then add further to the bad circulation, and be a contributory cause to the development of corrosion fatigue cracks.

The orientation of cracks over a tube surface is governed by the resultant of the stresses involved, to which the stresses imposed by the normal working pressure of the boiler will contribute. Thus, cracking may be circumferential, oblique, longitudinal or may occur at random in all directions. Inherent surface markings on the tube wall such as scratches, overrolling scores, pits, etc., often act as stress raisers, and influence the position and rate of cracking. Illustrations of this are given in Figures 20 and 21 and incipient cracks radiating from the root of a manufacturing defect are revealed in the microsection illustrated in Figure 54. When the cracking is completely at random it is described as "crazy cracking".

A full understanding of the condition resulting in the development of specific forms of cracking is useful to designers in indicating conditions existing in a particular boiler, and frequently metallurgical evidence has contributed in this manner to boiler design.

Corrosion Fatigue in Boiler Drums. Another source of corrosion fatigue is to be found in tube hole arbourings of steam and water drums, where static stresses may be inherent from the manufacturing operation and may be supplemented to a small degree by stresses imposed during steaming. However, such deterioration is usually coupled with deep selective pitting, and is not very frequent in its occurrence. An example of such cracking in the arbourings is given in Figures 22 and 23, but it must be noticed in this case that the tubes were not entering the drum radially, and the combination of the original machining operation in the arbourings, cold work during tubing operations, and corrosive conditions

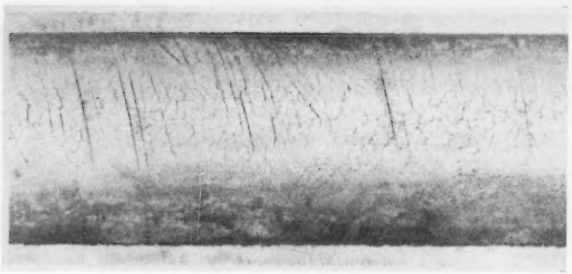


Figure 20—"Corrosion fatigue" cracks developing from spiral scores along the bore of a generator tube.

Figure 21—"Corrosion fatigue" fissures radiating from the base of pits.

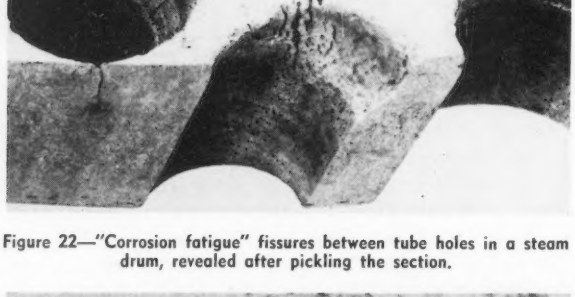


Figure 22—"Corrosion fatigue" fissures between tube holes in a steam drum, revealed after pickling the section.

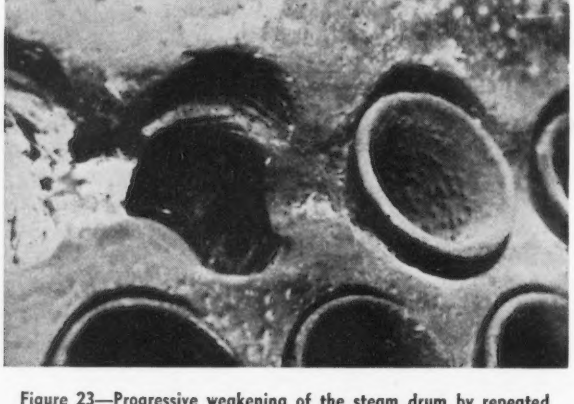


Figure 23—Progressive weakening of the steam drum by repeated attempts to grind away developing cracks.

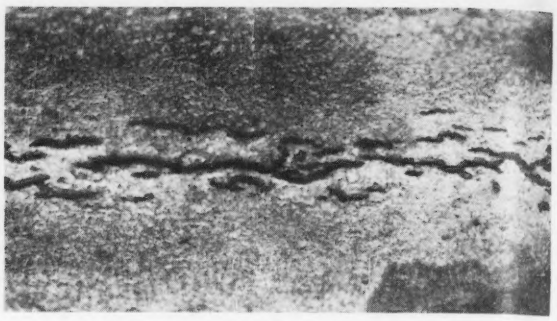


Figure 24—"Corrosion fatigue" fissures in the base of a corrugation in a main steam pipe.

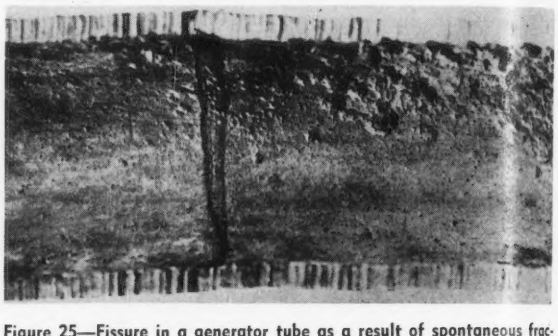


Figure 25—Fissure in a generator tube as a result of spontaneous fracture (following a milk shock) on a "strain aged" material.

during operations, all contributed to this failure.

Corrosion Fatigue in Main Steam Lines. Steam lines also exhibit corrosion fatigue cracking. An example is shown in Figure 24, which illustrates a fissure in the base of a corrugation. In this case it is possible that original surface roughening exerted an influence on the subsequent development of corrosion fatigue fissures. Frequency of stress application in this component was extremely small, and the fissures, one of which is illustrated in the photomicrograph Figure 39, had only penetrated to a small depth.

Many other examples of corrosion fatigue cracking have been reported from a wide range of both marine and land installations. For instance, desuperheaters are especially prone to this form of deterioration, as may be expected from the conditions under which they operate. Boiler components other than those enumerated frequently fail by corrosion fatigue cracking, and an individual examination of each case usually brings to light conditions which have existed and which have accounted for this form of deterioration.

Reduction to a minimum of corrosive conditions by water treatment will, of course, minimize this form of deterioration, and indeed may, if the stresses imposed are less than the fatigue limit of the material, result in its complete elimination.

Strain Age Embrittlement

Occasionally, boiler components have failed by spontaneous cracking, as a result of shock. Rivet heads are perhaps most frequently affected in this manner, although boiler tubes have been known to fracture immediately above or below a drum during a cleaning or a detubing operation. An instance of the latter is illustrated in Figure 25. This form of deterioration has been termed "strain age embrittle-

ment", and is directly connected with the reduction of impact properties of certain mild steels following cold work and ageing. The joint effect is to reduce the impact properties of the material to a very low value at room temperatures. At boiler operating temperatures, however, the impact properties of such strain aged material are substantially higher, and thus failure seldom takes place under operating conditions. Surface irregularities offered by sharp pits, or grooves caused during the tube rolling operation, offer favourable nuclei for the initiation of spontaneous rupture of the brittle steel.

Critical examination of a failed component frequently reveals conditions which have been responsible for inducing the cold work, as for example, the case of a failed tube end (Figure 25), which had been cold-worked by over-rolling, followed by repeated bending moments imposed immediately below the tube plate by tube movement during steaming periods. A small specimen removed from the affected area proved that the impact properties in this zone were very low at room temperatures.

Repeated tubing and detubing operations may induce cold work in the arbourings of tube plates, and although the stresses may be insufficient to result in spontaneous failing by cracking, they frequently encourage stress corrosion cracking. Annealing must be carried out in order completely to restore impact properties in the boiler component, but unfortunately strain age embrittlement gives no indication of its presence until spontaneous cracking has occurred.

Caustic Embrittlement

Although considerable attention has been devoted by a number of investigators to the causes of this form of deterioration, and opinions still remain divided, its appearance in marine boilers employing distillate feed is fortunately extremely rare. When it does occur, its presence is more likely to be found in such components as boiler plates, riveted seams, and under rivet heads, than in boiler and superheater tubes. It is more common in boilers using chemically treated raw water, where conditions for its development are more likely to be found. Caustic embrittlement results from a combination of causes involving quality of steel, non-uniform static stresses, elevated temperature, a high concentration of caustic soda, and possibly the presence of a catalyst such as sodium silicate. There are several schools of thought as to the relative importance of these influences.

Certain conditions of boiler water composition result in free sodium hydroxide being formed and concentrated in seams and crannies, mainly as a result of the combined influence of capillary attraction and evaporation. Under the influence of temperature, concentrated caustic soda attacks stressed steel in an intergranular manner, possibly by hydrogen absorption. The rate of attack is accelerated with increase in temperature and stress concentration. An example of a fissure which developed as a result of caustic embrittlement is illustrated in Figure 26, which shows a crack between riveted holes on a wrapper plate. Cracks associated with this form of deterioration progress through the steel in an intercrystalline manner, an example of which is illustrated in Figure 43.

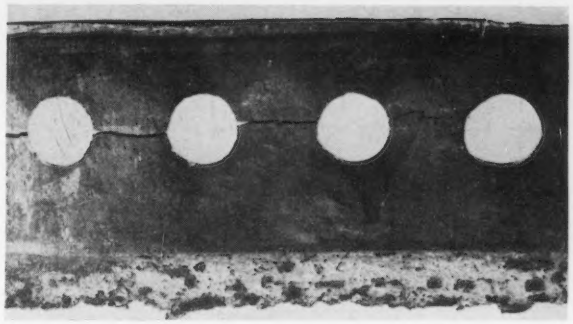


Figure 26—"Caustic embrittlement" between rivet holes on a wrapper plate.

This intercrystalline characteristic (in the absence of evidence of overheating above 500 deg. C. or 932 deg. F.) always distinguishes this form of deterioration from corrosion fatigue cracking, which has been discussed in a preceding section. Where alternating stresses are also present, corrosion fatigue fissures and caustic embrittlement may combine to give failure, which would then be a combination of inter- and trans-crystalline cracks. Alternatively, the rate of caustic embrittlement cracking may be increased, but in this case it would appear that alternating stresses are of must less importance than a combined chemical action and static stress.

It appears to be necessary for sodium silicate to be present as a catalyst before caustic embrittlement occurs, and work is still proceeding to establish the exact causes of this type of boiler failure and to formulate inhibitive measures to prevent it. So far, however, it has not been possible consistently to reproduce results. In the latter connexion there appears to be a definite retarding effect on this form of deterioration by powerful oxidizing agents, and sodium sulphate is used mainly in this connexion. The benefit of certain organic compounds for this purpose is also under investigation. Many data have already been published on the subject, and it is not necessary to mention them in any greater detail here. "Caustic embrittlement" is perhaps the most widely discussed form of boiler deterioration, but in point of fact remains by far the most infrequent encountered in boilers using distillate feed.

Deterioration at Elevated Temperatures

High Temperature Oxidation. In a general sense all types of corrosion which have been described in the preceding sections are a form of oxidation, since iron is converted into its oxide when corrosion takes place. The term "oxidation" can, however, be used in a more restricted sense, referring to the direct reaction between gaseous oxygen and iron which takes place at temperatures above 550 deg. C. (1,022 deg. F.). This form of oxidation may thus be more aptly described as "high temperature oxidation". The reaction which takes place when iron is heated in a current of steam to produce ferroso-ferric oxide is so well-known that it needs no description here, but the influence of time and temperature on the rate of the reaction plays an important part in the deterioration of boiler components by reduction of tube wall thickness. Under normal conditions of heat transfer in

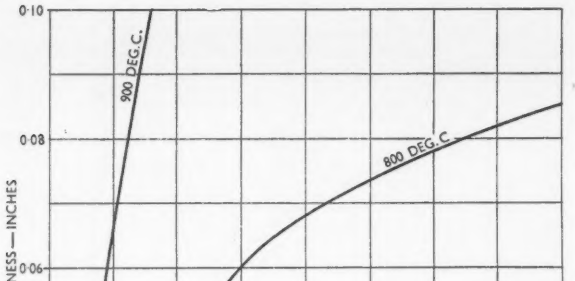


Figure 27—Relationship between time and decrease in metal thickness for mild steel in an atmosphere of superheated steam at various temperatures.

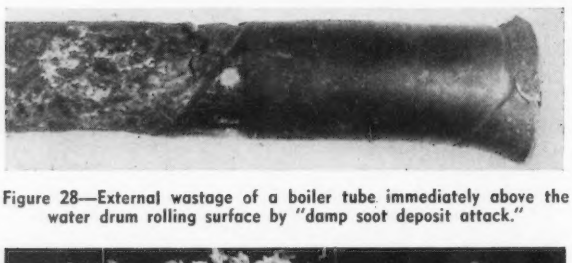


Figure 28—External wastage of a boiler tube immediately above the water drum rolling surface by "damp soot deposit attack."

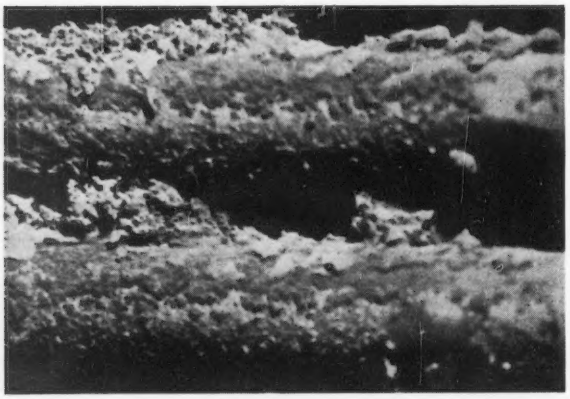


Figure 29—Accumulation of soot and ash from burnt oil fuel on superheater tubes.

generator and superheater tubes, temperatures are insufficiently high for direct oxidation to take place, but occasionally, as a result of fortuitous circumstances, excessive tube wall temperatures occur with consequent deterioration. Attendant on high temperature oxidation of tube walls are other forms of deterioration, such as bursting and the development of high temperature creep cracks. These latter phenomena are discussed in the following sections.

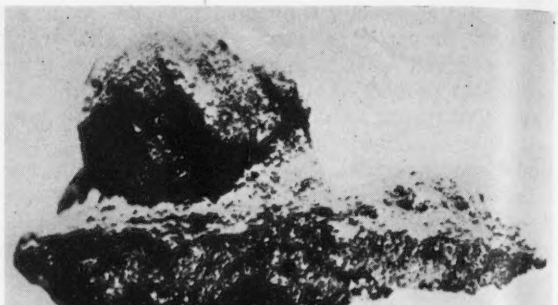


Figure 30—Enlarged view of a complete scab removed from a scab pit on a generator tube.

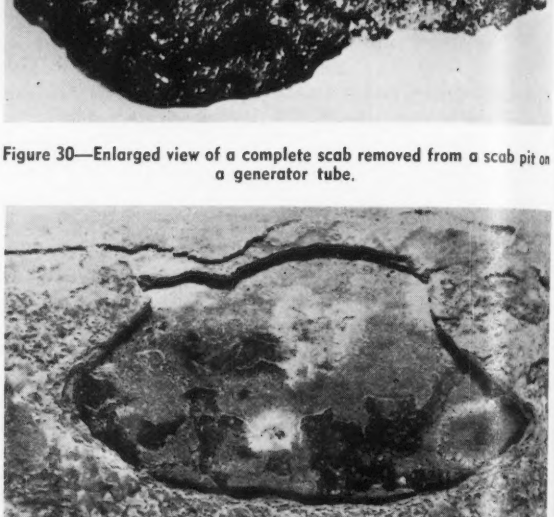


Figure 31—Thick red insulating blanket of "hard water" scale which has built up on the water surface of a fire tube, and which has been fractured to expose tube below.

The nature of the scale produced on generator surfaces by overheating often supplies evidence as to the conditions existing at the time of deterioration, and thus an understanding of the nature and rate of scale formation on steel surfaces, over a range of elevated temperatures, is valuable to the engineer. This subject has received attention by many workers, and a great deal of published matter is available. Curves expressing the relationship between the rate of scale formation and time for a range of temperatures have been obtained experimentally on sections of boiler tube steel and are given in Figure 27. Another phenomenon which gives evidence of the conditions responsible for the development of high temperature iron oxide scale is the crystalline structure which is frequently exhibited on the outer surface. It has been observed that higher temperatures promote the growth of correspondingly larger surface crystals, and a visual examination often gives an indication of the temperatures which have been involved.

High temperature scaling may occur in any parts of a boiler subjected to heat transfer, e.g. in generator tubes where water flow has been partially restricted. Some workers have shown that the rate of oxidation is slightly greater in air and carbon dioxide than in steam; thus it is often found that the layer of scale on

the outside of the tube surfaces is thicker than its corresponding layer on the bore, even when taking into account the fact that the outside surface temperature is a few degrees higher than the temperature of the bore. High temperature iron oxide scale is hard and black, and often appears as a series of scaly layers, but might equally exist as one thick layer, depending upon conditions existing during its development.

Where heat insulating scales from the feed water are allowed to build up on the steam generating surfaces, such as is illustrated in Figure 31, they stifle internal oxidation, but, by reducing the rate of heat transfer and thus increasing wall temperature, they encourage overheating and high temperature scaling of the outside walls in contact with furnace gases. Occasionally, due to general water starvation throughout the entire boiler, the whole of a boiler may in some small degree be affected by high temperature oxidation, and indeed, in one case brought to the authors' attention, water starvation was so complete that the iron steam reaction proceeded so vigorously that the reaction became exothermic. Only after the whole incandescent area was copiously flooded with water, was the reaction stifled. Often, the presence of high temperature oxide scale in a particular zone gives some indication of the heat distribution and water circulation in the boiler, and thus influences future modifications and improvements.

High temperature oxidation is found most frequently in superheater tubes, which operate at higher temperatures than boiler tubes and therefore are more susceptible to overheating, especially where steam flow has been sluggish. Frequently, a gradual increase in scale thickness from the inlet to the outlet end of a superheater tube indicates a progressive rise in tube wall temperature. On the other hand, local flame impingement, such as may occur around bends, gives a local area of high temperature scaling which may remain undetected until perforation occurs. An example of this is illustrated in Figures 32 and 33.

It must be remembered that once overheating of a heating surface has taken place and a layer of scale has been formed, the rate of heat transfer across the section is reduced, with a corresponding rise in tube wall temperature, so that oxidation and scaling proceed more rapidly than ever. Another factor which influences the rate of scale formation is the expansion of the layer of scale which accompanies oxidation, and the difference between its coefficient of linear expansion and that of the parent metal. This latter point, together with thermal stress liable to occur along the wall of a tube, and especially around bends, may cause layers of scale to flake away, and thus continually expose fresh overheated metal to oxidizing atmospheres with a consequent increased rate of deterioration. An example of this is illustrated in Figure 32. Examination of the micro-structure of an oxidized tube frequently shows marked decarbonization of the surfaces similar to that illustrated in Figure 45.

The precise assessment of boiler and superheater tube wall temperatures existing in a fired boiler is a difficult matter, and several methods are available to the engineer. The attachment of thermocouples to

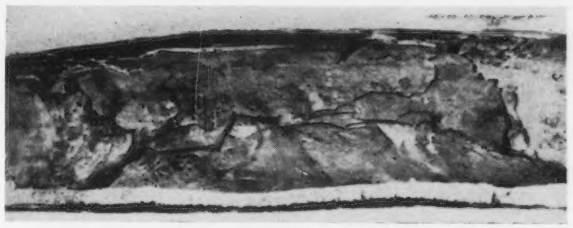


Figure 32—Layers of high temperature iron oxide scale.

Figure 33—Reduction in wall thickness to the point of perforation around a superheater bend by high temperature oxidation.

outside tube walls by "Jubilee" clips, brazing, peening, and other such methods have been found to give high results, mainly due to conduction back along the overheated leads to the hot junction. A new method, at present being developed, consists of passing the leads of a thermocouple through the tube wall by means of heat resisting plug insulators. A composite hot junction is then formed by the two arms of the couple touching the inner surface of the tube wall opposite to the insulators. This obviates inaccuracies due to conduction back along the leads to the hot junction, and detects small changes in wall temperatures on the steam generating surfaces.

While it is appreciated that this form of pyrometer would not be easy to install in a large number of representative points throughout a boiler, it could be used as a standard to assess the inaccuracy of simpler but more practical forms of tube wall temperature measurement over a wide range of operating conditions, which could then be disposed throughout the whole boiler. Up to the present, however, the engineer has had to rely on the more simple methods, the accuracy of which has often been questioned by the appearance of such forms of deterioration as high temperature scaling.

Distortion of boiler components often occurs alongside high temperature oxidation, but on the other hand this may develop at temperatures insufficiently high to cause scaling. In tubes, it usually results from the tube bank not expanding uniformly, when local strain or creep may result in buckling and distortion; an example of this is given in Figure 52. While this form of deterioration is not in itself serious, it frequently plays an important part in the failure of tubes as a result of corrosion fatigue cracking. This arises from the fact that once a buckle has been formed, any further strain induces bending moments around the buckles with high tensile skin stresses on one side of the tube. This greatly accelerates the development of circumferential corrosion fatigue cracks,

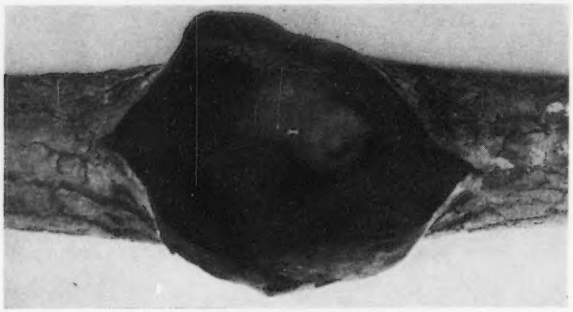


Figure 34—Burst in a generator tube subsequent to prolonged wall temperature of about 700 deg. C. (1,292 deg. F.)

Figure 35—Burst which occurred spontaneously as a result of a sudden rise in boiler tube wall temperature up to 950 deg. C. (1,742 deg. F.).

or, if temperatures are sufficiently high, causes exfoliation of developing layers of high temperature scale and the exposure of bare metal to oxidizing influences.

Some forms of superheater tube, especially those which have supporting lugs between the saturated and superheated legs, frequently distort by curling, due to differential expansions which may not be fully accounted for in the design. As will be shown in later paragraphs, such distortion in superheater tubes frequently plays an important part in the development of another form of deterioration termed "high temperature creep cracking".

Bursts. When bursting occurs in boiler tubes, it may, almost without exception, be traced to local or general water starvation, which has resluted in a rise in tube wall temperature. Causes of such starvation are many, and include abnormally low water levels, irregular distribution of hot gases in the furnaces causing faulty circulation, bad design, local flame impingement, foreign bodies left in the water drums, violent fluctuations in steaming rate and many other operational peculiarities which are outside the scope of this paper. Characteristic of the bursts often give an indication of conditions which have existed in the tube immediately prior to its failure. These include the actual dimensions of the burst, nature of scale surrounding the fissure, and the microsctructure of the material at the edge of the fissure and in adjacent zones. In some cases a rise in tube wall temperature is consequent on a build up of heat insulating scale from impurities in the feed water, or an accumulation of corrosion product sludge, often loosely bound together by oil or grease.

The actual mechanism of a burst is approximately as follows: water or steam starvation results in a progressive rise in tube wall temperature with a corresponding reduction in mechanical properties. A point is eventually reached where stresses induced in the tube wall by the working pressure of the boiler exceed the elastic limit of the material, and bursting ultimately occurs. Where the rate of overheating is relatively low, or is maintained at temperatures around 700 deg. C. (1,292 deg. F.), considerable swelling of the tube takes place prior to the ultimate fracture, and this form of burst is characterized by the ballooned appearance and the feathered edges of the split such as is illustrated in Figure 34. Where, however, rises in temperature have been sudden up to abnormally high temperatures (900-1,000 deg. C.) (1,652-1,832 deg. F.) ballooning does not have time to take place before catastrophic splitting occurs. Such a case is shown in Figure 35.

Frequently, microscopical examination reveals the edges of a fracture to have a martensitic structure, thus giving a positive indication that tube wall temperatures were in excess of 900 deg. C. (1,652 deg. F.) prior to the burst, which had been followed with drastic quenching of the edge of the fracture by the escaping water and steam. This sequence will retain a characteristic martensitic structure even in mild steel. A typical example of a coarse martensitic structure thus produced at the edge of a burst in a boiler tube is illustrated in Figure 48. Micro-examination of adjacent areas will often give evidence as to the extent of overheating along a particular tube, but frequently it is necessary to examine the whole tube bank before the true cause of the overheating is determined. Some intermediate structures often found adjacent to bursts are illustrated in Figures 46, 47, and 49, which should be compared with the microstructure of average quality boiler tube steel illustrated in Figure 44.

Distortion of ferrite and pearlite microstructure in the immediate vicinity of the burst, such as is illustrated in Figure 55, frequently indicates failure after plastic deformation following prolonged elevated wall temperatures, but below 700 deg. C. (1,292 deg. F.), which is the lower recrystallization temperature for mild steel. Where the tube has been at an elevated temperature for considerable periods prior to the burst, ultimate failure may be assisted by gradual weakening of the tube walls by the formation of high temperature scale, which in itself is a bad thermal conductor, and thus promotes even higher tube wall temperature.

Splitting of Superheater Tubes by "High Temperature Creep Cracking". While bursting is consequent on overheating of boiler tubes, a similar type of failure encountered at high temperatures in superheater tubes occurs mainly as splitting. Cracking may follow overheating, with corresponding reduction in mechanical properties, to the point of swelling and failure by splitting under the normal working pressure of the boiler, but more frequently it terminates a period of plastic deformation under the influence of stress and temperature, a phenomenon known as "creep". High temperature creep cracking is a form of intergranular weakness which is liable to be encountered in certain steels including low carbon steel. The temperature at

which this cracking takes place in a particular steel is termed its equicohesive temperature, and for mild steel is about 550 deg. C. (1,022 deg. F.). At this temperature, and depending upon other inherent characteristics, such as grain size, composition of the metal, etc., the grain boundary material of the structure becomes weaker than the aggregate, and thus, if in a state of stress, it fails by intergranular disintegration as is illustrated in Figure 42.

Although these cracks are similar in appearance to those formed by caustic embrittlement, they can be identified from them by virtue of the temperatures involved, which result in the development of layers of high temperature iron oxide scale both on the corresponding metal surfaces and within the cracks themselves. This form of deterioration has frequently been found where a difference in expansion has existed between the saturated and superheated legs of a superheater element. If such a stress concentration coincides with overheating, high temperature creep cracks develop, and ultimately constitute a penetration of the tube wall. Examples of this form of deterioration are illustrated in Figures 36 and 37.

General Wastage by Damp Soot. Accumulations of heavy deposits from the oil fuel on the fire side of boiler components are a common occurrence, and their effect in reducing boiler efficiency is well known. The nature and rate at which these deposits collect, and their preference for particular zones, depend very largely upon the quality of the fuel and the design of the boiler. So much attention has been, and still is being, paid to this subject with regard to fuel economy, that consideration need only be given here to the effect that these deposits have on the deterioration of metallic surfaces with which they are in contact.

Deposits on generator and superheater tubes have a shielding effect from the furnace gases, and thus in no way encourage high temperature oxidation, but severe wastage is often found on steel surfaces beneath such deposits when these are allowed to remain and become damp during the periods when the boiler is not steaming. Consequently, steel surfaces most likely to suffer from this form of deterioration are those which are not easily accessible for cleaning purposes. Typical examples may be found where water tubes enter water drums, and superheater tubes enter superheater headers, and an example of a boiler tube which had been thinned to the point of perforation immediately above where it entered a water drum, by this form of deterioration, is illustrated in Figure 28.

The most virulent forms of oil fuel deposits encountered in marine boilers are agglomerations of metallic oxides, sulphates, and chlorides, loosely bound together with carbonaceous matter. They are a mixture of green, white, yellow, and black salts, and are frequently partially fused together. Free sulphuric acid may also be present in varying amounts up to two per cent. Fuel oils from certain sources are rich in organic vanadium salts which, on burning, form vanadium pentoxide, having a low fusing temperature. This oxide exerts considerable influence on the physical properties of other components of the de-

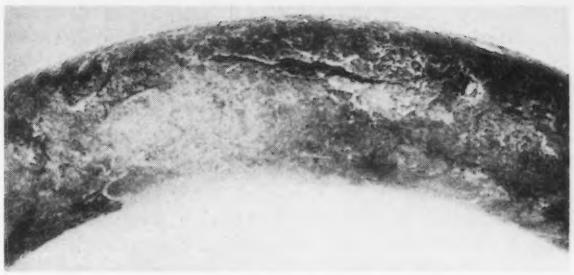
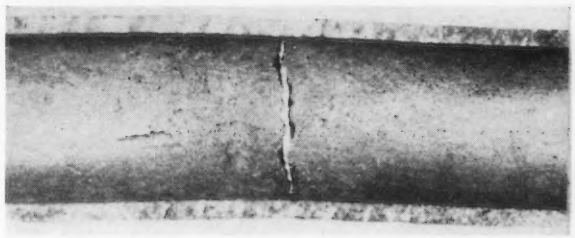


Figure 36—Failure by "high temperature creep" cracking around a superheated bend.



x 100 dia.
Figure 37—Perforation of a superheater tube in the centre of a buckle as a result of "high temperature creep."

posits, forming a eutectic of comparatively low melting point which runs over the tube as a slag and is very difficult to remove.

The presence of corrosive oil fuel deposits can be explained as follows:—Fuel oils may contain up to 1.5 per cent of sulphur which, when burnt, forms oxides of sulphur, some of which may be thrown down with the ash (mainly metallic oxides) and some unburn hydrocarbons. Perhaps the main source of ash in marine boilers is sea-water, which frequently finds its way into the fuel oil with which it forms an emulsion, thereby depositing large quantities of metallic sulphates and chlorides in the furnace.

Ash then tends to collect in stagnant corners or pockets in the boiler, particularly where there is reduced gas flow, such as between tubes and water drums towards the back of the tube bank, re-entrant corners, and blind passages. An example of such an accumulation on superheater tubes is shown in Figure 29. While the boiler is steaming, these assumulations are dry and inactive, but when the boiler is shut down, they absorb moisture as a result of the hygroscopic nature of some of the constituents. Dripping boiler components may substantially increase the moisture content, and it is not unusual to find free sulphurous or sulphuric acid being formed, which then trickles through deposits and dissolves metal with which it comes in contact by normal acid corrosion of the hydrogen evolution type. Some free sulphuric acid will combine with the metallic oxides in the deposits to form a variety of metallic sulphates, e.g. sodium sulphate, nickel sulphate, calcium sulphate, iron sulphate, etc. These metallic sulphates are usually hygroscopic and thus become acid in nature, thereby assisting in the corrosive attack on the adjacent steel.

Corrosion will proceed as long as the boiler is idle and damp, but when in operation, the deposits are

dried and attack is temporarily halted. Some oil fuels, depending upon their sources of origin, deposit more sulphurous compounds than others, but they are always present in some measure, and it is for this reason that the systematic removal of accumulated oil fuel deposits should be carried out at frequent intervals. Boiler design should include provision for ready accessibility of shielded areas, and much is being done in the development of water and steam lances, and soot blowers to facilitate cleaning.

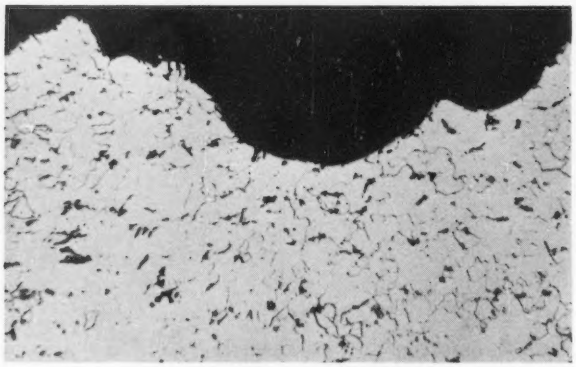
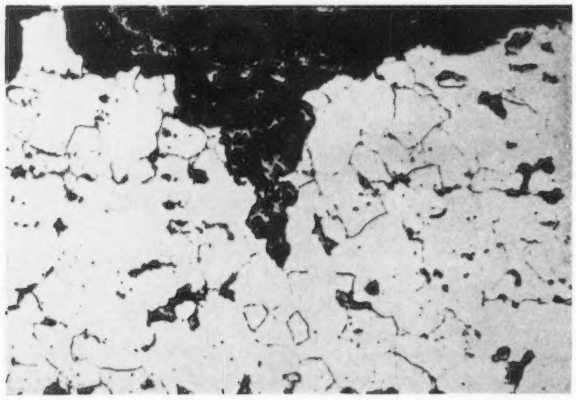
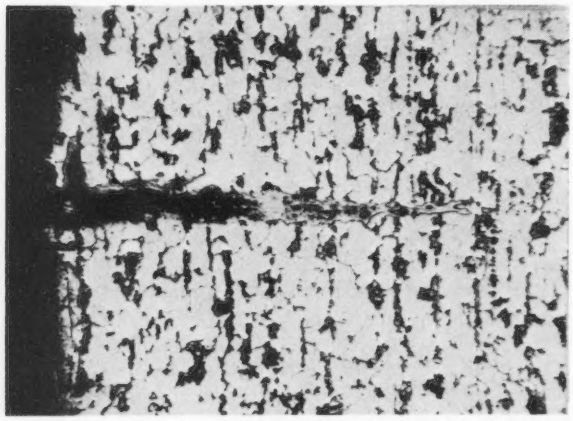


Figure 38—Photomicrograph illustrating the normal non-selective penetration of a corrosion pit into the surface of a boiler tube.



x 200 dia.
Figure 39—Broad transcrystalline corrosion fatigue fissure filled with corrosion products, resulting from low frequency "corrosion fatigue."

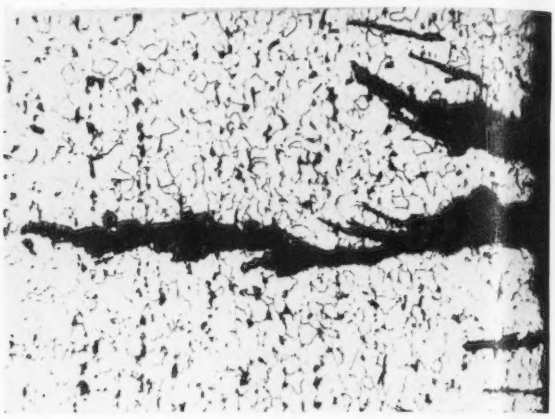


x 100 dia.
Figure 40—Transcrystalline "corrosion fatigue" fissure resulting from high frequency "corrosion fatigue."

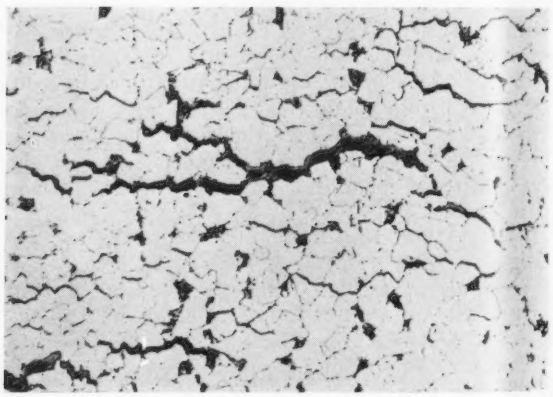
As an immediate means of minimizing this form of deterioration, attempts should be made to prevent the deposits becoming damp when the boiler is shut down, by giving continued attention to rain catchments, leaky tubes, and other sources whereby water gains access into the boiler furnace.

Conclusions

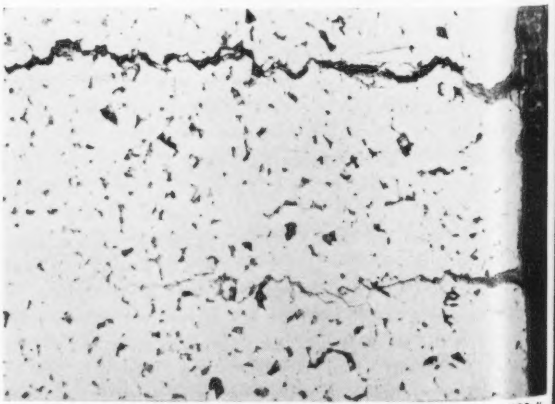
Deterioration in marine boilers is dependent in



x 50 dia.
Figure 41—Typical transcrystalline "corrosion fatigue" fissures in a boiler tube wall.



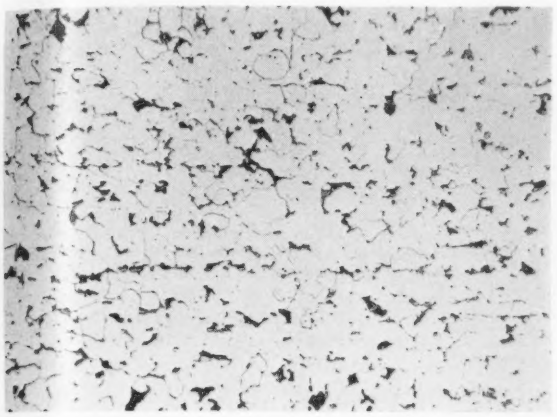
x 100 dia.
Figure 42—Intercrystalline "high temperature creep cracks" in a superheater tube wall. Secondary cracking has taken place to the point of intercrystalline disintegration.



x 100 dia.
Figure 43—Intercrystalline "caustic embrittlement" fissures penetrating a boiler plate.

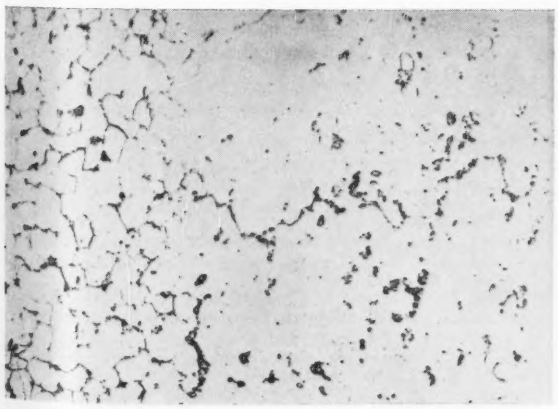
appropriate measure on a number of factors involving design, operation and, in particular, the control of water conditions when steaming and standing. Marine operation involves compact and often highly powered units where flexibility and irregular steaming intervals are the rule. Afloat, control of operating conditions and of boiler water lacks the more certain ease associated with that of the shore based power station.

As regards internal (water side) corrosion, the authors are impressed by the fact that the initiation of the damage all too often is consequent on careless attention during idle periods between steaming, and the role of oxygen, gaining access to the boiler water

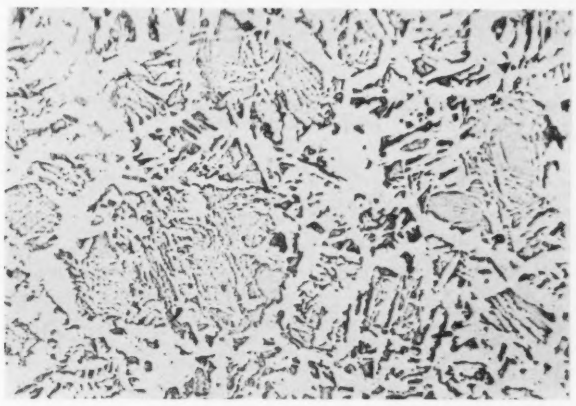


x 100 dia.
Figure 44—Typical microstructure of low carbon boiler tube steel.

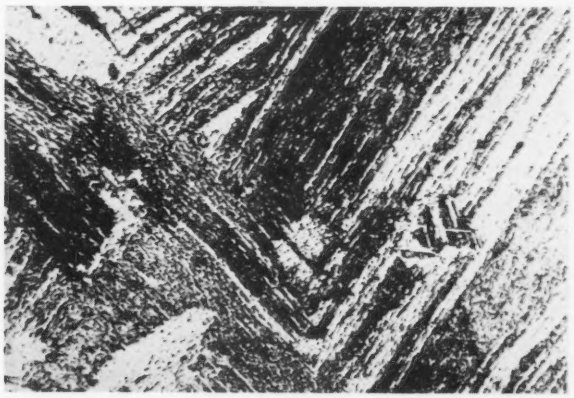
x 100 dia.
Figure 45—Heavy decarburization at the surface of an overheated boiler tube.



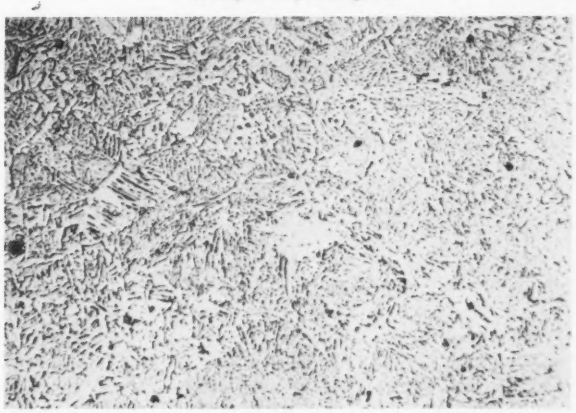
x 100 dia.
Figure 46—Spheroidization of the pearlite in a superheater tube wall as a result of prolonged heating at temperatures just below 700 deg. C. (1,292 deg. F.).



x 100 dia.
Figure 47—Coarse Widmanstatten structure subsequent on overheating followed by fairly rapid cooling.



x 100 dia.
Figure 48—Coarse acicular martensite retained in a low carbon steel boiler tube wall at the edge of a burst by drastic quenching from around 950 deg. C. (1,742 deg. F.).



x 100 dia.
Figure 49—Troosto-Sorbite in boiler tube steel formed by quenching between 750-850 deg. C. (1,382-1, 562 deg. F.).

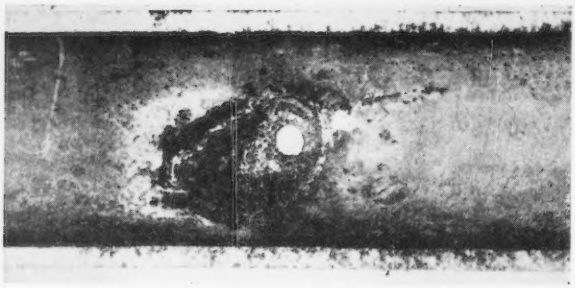


Figure 50—"Scab" pitting which has developed in a boiler tube wall to the point of perforation.

Figure 51—"Scab" pit in a boiler tube wall constituting a weak zone which ultimately failed by splitting at elevated temperatures.

Figure 52—Local bulging and distortion along a boiler tube wall resulting from restriction to expansion.

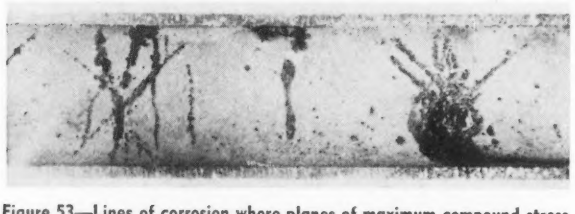
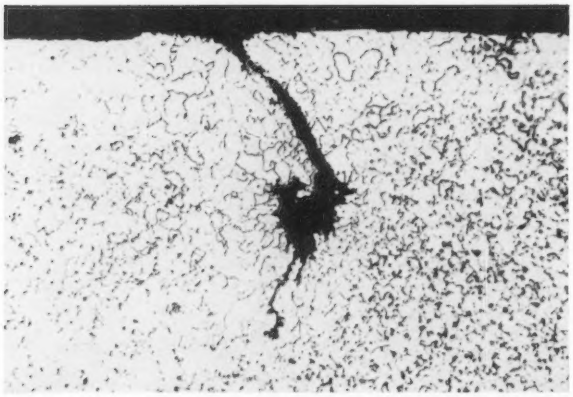


Figure 53—Lines of corrosion where planes of maximum compound stress have fractured normally protective surface films to initiate galvanic attack at the less noble bare steel.



x 50 dia.

Figure 54—Incipient corrosion fatigue fissures which have developed during service from a fold in a tube wall formed during tube manufacture.

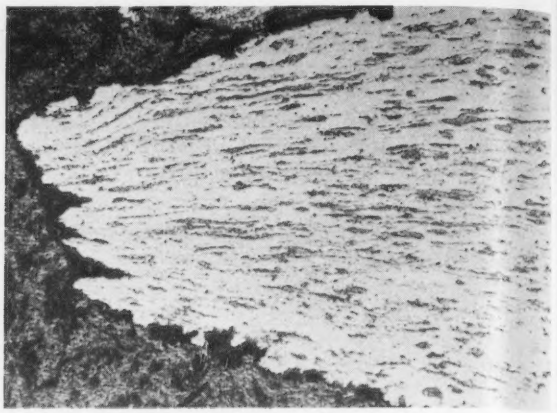


Figure 55—Distortion fo the microstructure in the vicinity of a burst which followed considerable plastic deformation by prolonged wall temperatures of approximately 650 deg. C. (1,202 deg. F.).

in such periods, must be particularly emphasized. External wastage is also a product of idle periods, and is further accentuated by inadequate soot blowing and cleaning.

Table 1, which classifies and discusses the several forms of corrosion and deterioration, is essentially a summary of the work now under discussion, and taken in conjunction with the several illustrations may be of some practical use to marine boiler designers and users as a ready guide to the subject. It will be noted that many forms of deterioration involve design factors, and the results of metallurgical investigations should provide substantial data from which modifications and improvements may be effected.

Acknowledgements

The authors carried out the work described above at the Admiralty Central Metallurgical Laboratory, and permission to publish this paper is gratefully acknowledged. Their thanks are also due to Mr. J. W. Messenger, B.Sc. (Eng.), who has assisted in some of the experimental work described and in the preparation of the illustrations.

APPENDIX

Bibliography

Boiler Availability Committee. 1946 Bulletin No. MC/153. Interim report on "External Deposits and Corrosion in Boiler Plant".

Colbeck, E. W., Smith, S. H., and Powell, L. 1943 *Proc.I.Mech.E.*, vol. 149, p. 63, "Caustic Embrittlement".

Evans, U. R. 1946 "Metallic Corrosion Passivity and Protection", Second Edition (Edward Arnold and Company, London).

Hall, C. E. 1947 *Trans. Inst. Marine Engineers*, vol. 59, No. 2, p. 34, "An Unusual Boiler Mishap".

Hamer, P., and Colbeck, E. W. 1944 *Chemistry and Industry*, 29th April, No. 18, pp. 163-165, "Caustic Embrittlement in Boilers".

Pfeil, L. B. 1929 *Jl. Iron and Steel Institute*, vol. 119, No. 1, p. 501, "The Oxidation of Iron and Steel at High Temperatures".

Reid, W. T., Corey, R. C., and Cross, B. J. 1945 *Trans. ASME*, vol. 67, "External Corrosion of Furnace-Wall Tubes". I—"History and Occurrence", p. 279. II—"Significance of Sulphate Deposits and Sulphur Trioxide in Corrosion Mechanism", p. 289.

Tapsell, H. J. 1944 *Proc. I.Mech.E.*, vol. 151, p. 54, "Creep Properties of Steels Utilized in High-Pressure and High-Temperature Superheaters and Steam Pipe Practice. Part I. Carbon Steels".

Turner, T. H. 1943 *Proc. I.Mech.E.*, vol. 149, p. 74, "Corrosion of Boiler Tubes".

Corrosion Problems in The Pulp and Paper Industry*

By DR. ROY P. WHITNEY

Introduction

SOME MONTHS ago, The Institute of Paper Chemistry, in cooperation with a large manufacturer of pipe and fittings, undertook to develop information regarding the nature and the extent of the corrosion problems which exist in the pulp and paper industry. The work was preliminary in character in that it was not aimed immediately at solutions to the existing problems. Its objective was rather to determine the feelings of the industry itself regarding the seriousness of the problems and the desirability of a concerted experimental attack which might aid in providing more information regarding the proper use of existing materials and, in some cases, better materials. From that standpoint, it is considered desirable to present the information which has been gathered. Therefore, it is the object of this paper to discuss, not answers to corrosion problems, but rather the opinions of a considerable number of pulp and paper manufacturers regarding the most serious corrosion problems with which they are currently faced.

DR. ROY P. WHITNEY

Research associate in chemical engineering at The Institute of Paper Chemistry, is in charge of general chemical engineering research (especially pilot-plant design). He holds degrees of S.B., S.M. and Sc.D. from Massachusetts Institute of Technology, where he was subsequently employed from 1935-45. He was professor and acting head of the department of chemical engineering at the University of Maine for two years before coming to the Institute in 1947.

For the purpose at hand, 79 manufacturers of pulp and/or paper (all members of The Institute of Paper Chemistry) were selected as providing a representative cross section of the industry, both geographically and as regards the various pulping and papermaking processes currently in commercial practice. These manufacturers were contacted by letter, in which the situation was outlined and in which they were asked specifically if they felt a comprehensive co-operative study of corrosion in the industry was feasible. Of the 78 manufacturers who replied, 56 indicated that they believed that such a study would be worth while and that they would be willing to cooperate actively in it. Five were undecided either as to the necessity for an experimental study or their participation in it, and 17 did not feel that a corrosion study was necessary. It is interesting to note that the greater part of the 17 negative replies came from companies with only papermaking operations (no pulping), in which the corrosion difficulties are comparatively less severe.

This response to the original letter indicated quite definitely that there are serious corrosion problems in the industry which, at least to the knowledge of the men who must deal with them, are unsolved. The next step taken was to contact again the 56 interested manufacturers, this time asking them to describe in detail their most troublesome corrosion problems, to indicate the materials or means used in attempted alleviation of the difficulties, and the success or lack of success attendant thereto. Thirty-one replies to this second request have been received thus far and it is these which constitute the basis of this paper.

The 31 above-mentioned manufacturers operate the following numbers of pulp and paper mills:

13 sulfite pulp mills,
11 alkaline pulp mills,
10 groundwood pulp mills, and
50 paper mills.

Since no mention of corrosion problems specific to groundwood pulping was made, no discussion is needed. The corrosion problems encountered in the other listed categories are discussed separately.

Sulfite Pulping

In the production of wood pulp by the sulfite process, wood chips are subjected to digestion by a sulfur dioxide-bisulfite solution at elevated temperature and pressure. The so-called cooking acid may contain from 6 to 10% total sulfur dioxide, of which 1 to 2% are combined as the sulfite of calcium, magnesium, sodium, or ammonia; it may exist in the digesters at temperatures up to 280° F and pressures up to 90 lb./sq. in. gage. During the acid preparation cycle, lower values of concentration, temperature and pressure exist. It is these strongly acid solutions which give rise to the most serious corrosion problems in the sulfite industry.

Almost all sulfite digesters are constructed of ordinary steel, with acidproof brick linings. Provided the lining is maintained properly, they give satisfactory service. Older plants still use considerable lead or

★A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.

lead-lined equipment for handling sulfur dioxide gas and cooking acid solutions at atmospheric temperature and pressure.

For handling both gas and liquor at elevated temperature and pressure, the preferred material is one of the stabilized stainless alloys such as Types 316 or 317. Almost all mills have completely replaced the bronze or brass fittings and lines previously used with these alloys, and many are using them instead of lead at low temperatures and pressures. Other stainless alloys find considerable use, although it has generally been found that the nonstabilized types are unsatisfactory. Several mills report good service from alloys of the 29% chromium-9% nickel type. One has had considerable success with an alloy little used in the industry, Type 329, and reports that it can be field-welded without carbon precipitation and subsequent corrosion near the weld.

Although the general feeling is definitely one of satisfaction with the stabilized stainless alloys, one of the interesting phases of this survey has been in pointing up the several instances of failure and inadequacy of these alloys. Almost without exception, these failures can be traced to conditions which might be expected to destroy the passive surface and to prevent its regeneration. Pure sulfur dioxide solutions, although strongly reducing, apparently do not attack the stainless steels appreciably. However, under conditions of continuous exposure to the cooking acid solutions with no chance for periodic cleansing or reoxidation, severe corrosion is apt to occur. An example cited by one manufacturer is the gasket surface at a flange in a stainless line. The line itself shows little corrosion, whereas the gasket surface rapidly develops severe pitting. Abrasive conditions in the presence of the reducing solutions are also cited, as are air-cooking acid interfaces, and the presence of appreciable concentrations of sulfur trioxide. The industry knows of no solution to these problems.

Also associated with cooking acid preparation is the combustion of sulfur and the cooling of the hot burner gas thus formed. One specific problem involves the introduction of molten sulfur to the burners for which no metal appears to stand up satisfactorily. In one instance, Type 316 stainless steel gives about two months' service. Another involves handling of the hot gas, which may be at a temperature of about 2300° F as it leaves the burner. For the hot gas, cast iron is most commonly used but is a source of difficulty. One mill has tried Types 302 and 347 rolled plates without success, and is now trying Type 316 cast stainless and nickel cast iron.

Alkaline Pulping

The alkaline pulping processes depend, as the name implies, upon the action of alkaline solutions for the delignification of wood. In the soda process, the cooking liquor is a solution of sodium hydroxide, usually containing some sodium carbonate. In the kraft, or sulfate, process, the cooking chemical is a mixture of sodium hydroxide and sodium sulfide, with some sodium carbonate and sodium sulfate usually present. Because the processes are essentially similar and because corrosion is usually much more severe in kraft pulping, attention will be directed to that process.

Kraft cooking liquors may contain from 10 to 12% total alkali, with a "sulfidity" (percentage of total alkali present as sulfide) of from 15 to 30%. The pressure in the digester may be as high as 130 lb./sq. in. with a temperature up to 350° F. After digestion, the "black liquor," now containing large quantities of dissolved organic matter, is separated from the pulp by washing, concentrated to 55-60% total solids by multiple-effect evaporation, and burned. The sodium carbonate-sodium sulfide smelt from the furnace is dissolved in water to form "green liquor," which is then causticized with lime to regenerate the pulping solution ("white liquor") used in the digesters. Make-up chemical to the system is usually solid sodium sulfate, which is added to the concentrated black liquor immediately before the furnace. Corrosion difficulties are experienced throughout the whole cooking and recovery cycle.

In contrast to the situation in sulfite pulping, there is no general similarity in the problems encountered in the various mills. In some cases, the greatest problem is in the digesters and in the dilute black liquor system. Others find particular difficulty with the hot concentrated black liquor and still others find the causticizing system most troublesome. In most of the older mills, the original materials of construction were steel and cast iron. These materials have been found wanting in many instances, and have been or are being replaced in the particular locations of most difficulty. In these replacements and in new installations, a variety of materials is being used. Most mills believe that excellent performance would be demonstrated by Types 316 and 317 stainless alloys, but feel that extensive use of these alloys cannot be justified economically and that other, cheaper, materials should prove adequate.

Kraft digesters, for the most part, have been of steel construction. Corrosion has been sufficiently severe to make other materials attractive and several stainless-clad digesters are in operation. In the multiple-effect black liquor evaporators, it has become fairly common practice to use tubes of Type 302 or 304 stainless alloys in the first two effects, since these effects usually handle the hottest and most concentrated liquor. One mill has gone to Type 316 or 317 stainless tubes for these effects and for the piping system between the evaporators and the furnace.

Because these liquors are strongly alkaline, nickel alloys should be of advantage, and the survey indicates they are being used considerably, particularly in causticizing and white liquor systems. Nickel-copper-iron alloys of the Ni-Resist type are satisfactory in many cases, and steels or cast irons containing 3-6% nickel are finding considerable use. For the evaporation of caustic solutions, usually saturated with salt (from brine electrolysis), tubes of high nickel alloys such as Monel metal are fairly standard. For either white, green, or black liquors, 3-6% chromium alloys appear to be completely unsatisfactory,

but the 12-14% chromium alloys stand up well in some cases.

In the combustion of black liquors, the flue gases from the furnace contain high percentages of water vapor, the usual amount of carbon dioxide, some sulfur dioxide, and large quantities of sodium sulfate dust. It is necessary to recover as much of the dust as possible in scrubbers, precipitators, or the like; this usually necessitates the cooling of the gases below the dew point. The liquid phase which forms is acid and very corrosive. Although it is presumed that stainless steel would meet this requirement satisfactorily, most mills have not found this solution feasible and the problem is a serious one.

Practically all the producers of kraft pulp concerned in this survey feel that they have a serious corrosion problem. The difficulties are more specific than general and there is some indication that they may be regional—the problem appears to be most severe in the Pacific Northwest. This is presumed to be associated with the wood species pulped and with their chemical composition and behavior. As with most industrial problems, satisfactory solutions must be based on economic as well as technical considerations.

Bleaching

The bleaching of chemical wood pulps is almost universally conducted with chlorine and chlorine compounds. In a typical multi-stage bleaching operation, chlorine gas or chlorine water (a solution of chlorine in water) is used in the first stage. This is followed by a caustic extraction stage using sodium hydroxide, which in turn is followed by one or more oxidation stages with calcium or sodium hypochlorite. Chlorine dissolves in water with the formation of equimolal quantities of hypochlorous and hydrochloric acids and, thus, the medium in the first stage has a very low pH (usually less than 2) and a high chloride ion concentration. The hypochlorite solutions used in the latter stages are well on the alkaline side (pH about 11 to 12) and also contain high chloride ion concentrations.

It is well known that the handling of hydrochloric acid solutions presents a very difficult corrosion problem. The problem appears to be equally difficult when hypochlorous acid is also present, and no completely satisfactory construction materials are known for these solutions. Although the attack becomes progressively less severe with sodium and with calcium hypochlorite, these solutions also present many difficulties.

For handling moist chlorine gas, chlorine water, or pulp slurries containing dissolved chlorine, the nonmetallic materials appear to be most satisfactory. Glass and acidproof tile stand up well, but are rather limited in practical application. Although several mills discussed experience with glass pumps and piping, this material is distinctly limited because of its mechanical properties. Tile is used extensively for lining bleach tanks and bleachers of various designs. Hard rubber, rubber-lined pipe, and rubber-covered equipment usually show good performance and are used extensively where feasible—for example, in washers for the chlorinated stock. Haveg is being utilized to some extent, and Saran is being investigated. For the acid bleach solutions, some failures with Saran have been reported. Considerable interest is evidenced in protective coatings of various sorts, of which chlorinated rubber paint is an example, but performance has been poor.

Although the nonmetallic materials are used whereever possible, the need for satisfactory metals is acute. Brass, bronze, steel, cast iron, and the stainless steels are, of course, completely unsuitable. Among the best of the metals are lead, Hastelloy C, and the 14% silicon cast irons (particularly Durichlor), but all the materials have serious limitations. Lead creeps badly, is subject to serious erosion, and exhibits only fair corrosion resistance. Hastelloy C often shows a relatively short life, is costly, and is difficult to handle. The high silicon cast irons are costly, brittle, and difficult to handle but, in the few instances mentioned, appear to show good corrosion resistance. All in all, a more satisfactory metal for this service is badly needed.

Although steel generally is considered to be a satisfactory material for handling liquid chlorine and dry chlorine gas, several comments indicate some difficulties in such systems. The difficulties may be largely traceable to the presence of moisture, which may have backed up into the chlorine piping from the bleach-making system. Several mills use Hastelloy C chlorine valves where this possibility exists.

It has been mentioned that the problem is much less severe in the case of the alkaline hypochlorite stages but is still troublesome. Sodium hypochlorite solutions are considerably more corrosive than those of calcium hypochlorite, the difference apparently lying in the presence or formation of insoluble sludges with the calcium bleach which coat the equipment and protect the original material. For either solution, steel, black iron, and wrought iron generally are unsatisfactory, but cast iron is considerably more resistant and is used in many instances, particularly with calcium hypochlorite. Transite finds considerable use, a popular combination being Transite pipe with cast iron fittings. Rather surprisingly, several of the stainless alloys show fairly good corrosion resistance, although their performance appears to be spotty and there are marked differences of opinion regarding their suitability. Hastelloy C and the 14% silicon cast irons stand up well but suffer from the drawbacks mentioned above. Saran is considerably better in alkaline hypochlorites than in acid chlorine solutions; a relatively new Saran-lined steel tubing is interesting.

One rather serious problem which exists around bleach plants is the general corrosion and rusting of the exteriors of piping, equipment, and structural steel. During much of the bleaching and washing of the pulp, the slurries may be exposed to the room and small quantities of chlorine gas are liberated. The chlorine, in the high humidity air which usually exists, is very corrosive to iron and steel. Examples can be cited where even stainless steel had failed

from exterior corrosion. The problem is not confined to chlorine, but is present as well in sulfite pulping operations where sulfur dioxide may escape, and to a lesser extent throughout the mills. Many protective coatings have been and are being investigated, with results which range, in the words of one manufacturer, "from indefinite in most cases to downright poor in several."

Papermaking

Although the products of papermaking run the gamut from facial tissue to bond to wrapper to board, the general nature and sequence of processing operations are remarkably similar. Wood pulp, cotton rags, reclaimed waste paper, or cellulose from other minor sources, either separately or in combination, are reduced to a fibrous suspension, further bleached or deinked if necessary, and "refined" in a beater or other refining engine. In the refining operation, the fibers are subjected to mechanical action which leads to the development of strength and other desirable characteristics in the finished sheet. During or after refining, the furnish is dyed, if necessary, sized and fillers are added. The furnish is then screened, diluted as required, and fed to a continuously operated paper machine which converts the dilute aqueous suspension into a finished dry sheet.

With a few specific and notable exceptions, the corrosion problems associated with papermaking are not of the severe nature encountered in pulping and bleaching. They are, nonetheless, important in the successful operation of the plant. In many instances, the necessity for extreme cleanliness in the product is as important in corrosion considerations as is the life of the equipment involved.

If, as is often the case, bleaching is conducted in the paper mill, the problems are the same as those discussed above and need not be considered further. Other specific problems arise with certain more or less specialized operations which require the use of sulfuric acid, hydrochloric acid, or other specific chemicals; these problems are often difficult but are not common to the industry as a whole.

One severe corrosion difficulty common to most of the industry arises in connection with sizing. Sizing may be done in the beater or later in the system. The most common sizing material is rosin, which is added as a mildly alkaline emulsion and offers no corrosion difficulty. The size is then precipitated with alum, which is added in an aqueous solution varying in concentration from 10 to 50%. The alum solutions are acid and difficult to handle. Copper, brass, iron, and steel are unsatisfactory as container materials. Lead is used extensively, but gives only fair service. Rubber appears to be reasonably satisfactory, except in a comparatively few instances. The reports on Type 316 stainless steel are confusing and contradictory. The few reported instances of the use of the 14% silicon cast irons indicate that they stand up well, but emphasize again the shortcomings of the materials. One mill has adopted the dry feeding of solid alum to the machine chest.

For the effective precipitation of the size on the fiber, it is necessary that sufficient alum be added to adjust the entire furnish to the acid side. This gives rise to the most generally experienced and most serious corrosion problem in papermaking. The condition of the furnish as it is fed to the paper machine varies with the particular mill and with the grade being run, but pH values range from 4.0 to 6.5 for sized sheets, at temperatures from 40 to 140° F. Although these conditions are not severe, the combination of product quality and equipment life dictates the use of materials other than iron and mild steel for much of the paper mill system.

Beaters, jordans, and other refining engines are for the most part constructed of steel, although many mills cite the rapid deterioration of all or portions of the refiners. Wooden and copper-lined beater tubs are quite common. Stock chests are, for the most part, tile lined. Stock and white-water piping may be copper, bronze, Transite, rubber lined, wood or wood lined, or Type 302, 304, or 316 stainless steel. Of these, it is the consensus that the stainless steels are the only truly satisfactory materials, but economic considerations preclude their use in many instances.

Choice among the various piping materials listed depends primarily upon the particular operating conditions. Copper and bronze are reasonably satisfactory in the higher pH range; Transite has a very limited use; wood or wood-lined pipe is difficult to install and maintain, and contributes to the slime control difficulties.

Conditions at the wet end of the paper machine parallel those in the stock piping. Headboxes, screens, stock inlets, white-water trays, and the like are constructed from a variety of materials, of which stainless and stainless-clad steels are most satisfactory. Brass and bronze are used extensively around the paper machine, but show considerable tendency for dezincification and destannification if the pH is low. Monel metal gives good service in many cases. Again, a considerable interest in the development of more satisfactory lining and coating materials is noted.

In mills producing high brightness papers particularly, rust and scale from water lines, steam lines, and the like may cause as much difficulty as dirt from the actual papermaking equipment. Again the problem is both economic and technical: how can this source of difficulty be controlled without recourse to the premium-priced alloys?

General

The discussion above has been limited for the most part to problems specific to the pulp and paper industry. Other problems, no less serious in many instances, but more general, could be cited. Among these are corrosion in fresh-water lines, in water-treating operations, in boilers, steam lines and condensate return systems, and by atmospheric exposure. These problems will not be discussed in this paper.

Summary and Conclusions

This report discusses in some detail the more im-

portant corrosion problems encountered in the pulp and paper industry. The difficulties specific to sulfite pulping, alkaline pulping, bleaching, and papermaking are discussed separately. Some of the conditions are so severe that even the most resistant materials are found wanting. For the most part, however, materials reasonably satisfactory from the corrosion standpoint are available, but in many instances mechanical shortcomings or high cost make the development of other materials extremely desirable.

The very severe conditions encountered in sulfite pulping are met satisfactorily most frequently by the stabilized 18-8 stainless alloys. These alloys are generally adequate also in alkaline pulping but, in many instances, are difficult to justify economically. The problems encountered in bleaching wood pulp cannot be met satisfactorily with the presently used metallic materials.

In illustration of a difficult but not unduly severe problem, the paper mill stock and white-water systems are cited. Here the mildly acid conditions and moderately elevated temperatures preclude the use of iron and steel, and no other completely satisfactory material except the costly stainless steels is available. The provision of suitable materials for such services at moderate cost would fill a pressing need in the industry.

Plant Corrosion in the Fatty Acid Industry*

By R. J. PAUL

Abstract

A paper giving a brief outline of materials used for equipment, pumps and piping in the older processing methods followed by a summary of new material applications in recent process, changes and improvements being made in the industry to raise product quality, reduce maintenance and to convert the industry from batch to continuous operations.

Plant departments such as raw grease handling and cleaning, splitting or hydrolysis, distillation and separation provide convenient divisions for discussing the application and relative merits of various corrosion resistant materials under several conditions of temperature and product purity.

Specific corrosion rates in ipy or mils are not presented, but in preference, the relative suitability of materials as indicated by the results of operating specific equipment under plant conditions, are discussed.

ABOUT THE AUTHOR: Engineer with Emery Industries, Inc., Cincinnati, Ohio, engaged in design of process units and equipment for various phases of fatty acid processing and corrosion and material research on special problems of high temperature and pressure fatty acid processes. University of Cincinnati, Ch.E. Member NACE and AIChE.

THE FATTY ACID industry, as such, in this country is well over 100 years old. Early developments by the author's company were for the production of stearic acid used in candle manufacture. The industry has developed from this early pattern into a basic chemical producer supplying many other manufacturers with raw materials of high standards of quality and purity. The fatty acids with which the company is concerned are of two types, saturated and unsaturated, both occurring in animal and vegetable compounds of an oily or fatty type, classed as glycerides. The saturated fatty acids, represented by stearic acid, normally are solid at room temperature while the unsaturated acids, represented by oleic, are liquid. It is the hydrolysis or "splitting" of the glycerides to their component glycerine and mixed fatty acids, and the subsequent separation and purification of these acids which form the basic processes of the industry.

Until recent years, very little information was published or available on corrosion in this industry. During the past 10 or 15 years, various metal fabricators[1] have published application information and recently several articles have been published summarizing available data.[2,3] However, most information has been developed by each organization by trial and error and research and has remained unpublished. Some of the information published[3,4] is not, therefore, universally true and may even be misleading. For example, the straight chrome (400 series) stainless alloys are listed[4] as being satisfactory for fatty acid use which is not the case in most applications. An excellent general reference is also available.[5]

Early use of fatty acids did not involve hydrolysis. Instead tallow or similar fats were "saponified" with lye or potassium hydroxide obtained from wood ashes, to produce crude soap. However, both the soap manufacturer and the fatty acid producer now split greases.[2,6] It was discovered early that boiling with sulphuric acid resulted in partial hydrolysis of greases to fatty acids, the glycerine concentration of the water phase limiting the extent of the reaction (at temperatures used with operation at atmospheric pressure). Sulphuric acid, of course, introduced corrosion problems, particularly in the boiling vessels and equipment handling the "sweet water." The grade of acid used is "chamber acid" for which steel is satisfactory as long as air and moisture are excluded. However, the boiling process is usually by open sparge steam, resulting in the formation of hot dilute aerated sulphuric acid solutions with attendant corrosion problems. Early acid hydrolysis was in wood boxes and was frequently done in several stages

*A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.

to obtain the desired degree of split prior to the pressing operation used to separate the solid and liquid fractions or stearic acid and red oil (mostly oleic acid), the latter deriving its name from the color resulting from dissolved iron compounds—corrosion products from presses, pans and other equipment.

In the latter part of the 19th century, an hydrolysis catalyst was discovered called Twitchell's Reagent, which was quite revolutionary as it greatly increased the rate and extent of hydrolysis and very little acid was required. Sometime in this period, lead lining of the wood boxes was introduced. With the reduced acid concentration of Twitchell splitting the mechanically better metal, copper, came into use. By re-skirting or the use of thicker metal at the liquid line where corrosion of the copper is quite rapid, as much as two years life might be expected before acid and grease leaks rotted the wood box to such an extent that replacement became necessary. For Twitchell splitting several recent applications of Monel vessels or linings appear to be giving excellent results. Additional plant experience is still needed for full evaluation.

With ever increasing costs of operation, it has been necessary for the fatty acid industry (and soapmakers as well) to process lower and lower grade raw materials while still maintaining the desired quality of product and a reasonable operating margin. As in other industries, this has been possible largely by change from batch to continuous processes. The use of low grade stocks and vegetable "foots" required an acid boil prior to splitting to remove proteins, bone and other impurities and also the use of a large strainer in pumping lines to separate out rags, bolts, shoes, and similar impurities when unloading tank cars. Lead lined wood boxes have been used extensively,[3] but certainly are far from satisfactory from a maintenance and operating viewpoint. Acid brick construction also has been tried and is highly satisfactory for moderate temperatures in such operations as emulsion separation, dilute acid storage and sweet water neutralization. For higher temperatures, such as acid washing and Twitchell splitting, results have been less satisfactory, probably because of stresses in the walls resulting from the considerable temperature changes occurring in batch operations.

A wrought material, with at least moderate physical strength, in a price range not exceeding stainless steels, and with resistance to sulphuric acid in concentrations from chamber through the complete range down to 10 percent or lower, and at temperatures in the range of 70° up to 215° to 230° F., with aeration, would be as welcome in the fatty acid industry as elsewhere.

Raw greases of all grades are handled in steel tank cars practically without exception. Storage in steel tanks is also the usual practice even when immediate splitting and storage of raw mixed fatty acid is used to reduce glycerine loss.

Separation of solid and liquid fractions continued to be a pressing operation for many years. Use of several stages of cold and hot pressing resulted in an excellent quality of stearic acid, which methods are still extensively used. The red oil produced, however, is of lower quality and requires considerable processing to obtain the highest quality grades. Today presses, plates, etc., still are usually made of steel and cast iron except in final finishing stages where Ni-Resist or aluminum may be used. Chilling pans of enameled iron, aluminum and stainless steel have been used. The first does not resist the rough usage involved and the latter are relatively expensive. Aluminum pans may be expected to have a useful life of several years.

To improve quality of product, a distillation operation was inserted between hydrolysis and pressing. This was also a batch operation using a large, direct fired, cast iron pot with copper vapor pipe and condenser. Some method of obtaining vacuum also was required, either a mechanical pump or, a barometric condenser and wet vacuum pump. Early vacuums were not high, possibly 27-28 inches. However, considerable color in the product resulting from corrosion products and other reasons, could be removed by this method and the operation is still basic in the industry.

Probably the first department in fatty acid production to convert to continuous operation was distillation. One type of still introduced into this country from Germany in the early 30's (Wecker) and still in use, consisted of a number of large direct-fired vacuum pans cast in aluminum bronze, with large wrought copper vapor pipes and condensers with aluminum tubes and sheets. A steam heated preheater had a bronze tube sheet, copper shell and cupro-nickel tubes. Life of large castings has been excellent but replacements have been with Ni-Resist, partly due to inability of American foundries to reproduce the German grade and quality of bronze and also to the gradual elimination of copper and its attendant product discoloration wherever possible. Copper liquid fatty acid lines were replaced by cupro-nickel and later by Inconel or Type 316 stainless steel. Retubing with aluminum condenser tubes was continued until recently when one section was completely replaced by Type 316 stainless steel. The same change to Type 316 stainless steel also was made in the preheater. Other later units also could be cited with their gradual conversion to most recent material developments.

With the development of the austenitic stainless steels and their fabricating technique during the past 10 years, all recent installations have used these materials extensively. Their successful application to auxiliary equipment has also greatly improved the quality of product and reduced maintenance due to corrosion. Use of stainless steel and Ni-Resist for booster and ejector diffusers and nozzles and for condenser castings has made possible the use of vacuums (at booster suction) in the range of 7 down to as low as 1 mm absolute, with complete dependability, and negligible replacement of parts. Recent developments in instrumentation have also made possible completely automatic control of feed rates and temperatures with improved quality and uniformity of product.

The concurrent development of stainless steel cen-

trifugal pumps and a number of types of corrosion resistant rotary seals with their elimination of packing difficulties, has made possible the successful application of this type of pump to the continuous pumping of still distillates and residues from receivers kept continuously under still vacuum. Formerly, a gear pump was necessary for this operation and as stainless steel gear pumps could not be obtained, bronze units, entailing high replacement rates, were necessary.

Feed tanks have been entirely of copper in the past. Recent trends have been to the use of 316 stainless steel. However, experience indicates that small amounts of sulfuric acid sometimes remaining in Twitchell split stock is highly detrimental and until such time as this type of stock is eliminated, Type 316 stainless steel should be used with care, or possibly Monel used in preference. In general, feed process piping is of Type 304 stainless steel on low temperature operations and Type 316 stainless steel where fatty acid temperatures exceed 250° F. Similar ranges apply to equipment such as heat exchangers and stills.

Product piping and receivers for condensed distillates below 180° F. may be of aluminum, but this metal gradually is being replaced by Type 304 stainless steel in these applications. The primary reason for the use of aluminum was elimination of color, due to the formation of metallic soaps, such as results with iron, steel and copper. Aluminum vessels are attacked by fatty acids, especially where moisture is present, resulting in pitted or grooved bottoms. Pipe lines also tend to corrode through on the bottom of horizontal runs, especially when periodically steam-blown to clear the line, as on interdepartmental transfers.

Separation of solid and liquid fatty acid fractions has also been converted to a continuous operation by the use of solvent separation by the Emersol Process.[7,8,9] Temperatures involved are relatively low. A maximum of 150° F. will liquefy most feed stocks, and this is followed by refrigeration of the fatty acid-solvent mixture to the neighborhood of 20° F., depending on type of feed stock, desired products, and other variables. Evaporation and stripping to remove solvent may require temperatures in the range of 220° to 240° F. Original equipment and process piping was mostly of aluminum. Due to the presence of water in various parts of the process, and for mechanical reasons, aluminum has been replaced by Type 304 stainless steel to a large extent. For vessels such as evaporators and stripping stills, use of Type 347 stainless steel may be preferable. The only higher alloy equipment used may be pumps—primarily because of manufacturers standardizing on one general-purpose alloy construction.

Except for special processes such as hydrogenation, esterification, fractional distillation and nitrile-amine production, carried on by various individual fatty acid producers and related industries, the most recent change in fatty acid processing has been the introduction of continuous pressure splitting or hydrolysis to replace Twitchell and acid splitting. The basic idea is by no means new but technical problems involved could not be solved without the advent of modern corrosion resistant materials, pressure vessel and welding techniques and development of special auxiliary equipment, such as pumps, instrumentation, and control and pipe line valves. Feed stocks can be any of a wide variety and grade of animal and vegetable fats and oils of varying free fatty acid (F.F.A.) content.

The main reaction vessel must be corrosion resistant to mixed fatty acids, in a probable range of 8 to 22 carbon structures, at temperatures of or near 500° F. in the presence of water, which must be maintained in the liquid phase by pressures somewhat above saturation pressure. Materials and types of construction for existing and proposed vessels vary considerably. Original and all subsequent vessels installed by the first commercial user[2] of the process are of solid alloy construction using Type 316 stainless steel. To obtain the necessary corrosion resistance, the entire vessel must be heat-treated at approximately 2000° F., water quenched through the critical range, and still obtain a vessel within the desired straightness tolerances, a considerable problem on a vessel roughly 2 to 2½ feet in diameter and 60 to 80 feet long. Recent tests[10] indicate that a special grade of Type 316 stainless steel having a carbon content of approximately .02 percent has excellent corrosion resistance and freedom from intergranular attack even in the welded and unheat-treated condition. At least one vessel, using this material as a liner, has been built for this service.

Inconel also has been used for the corrosion resisting parts of reaction vessels. This alloy has a corrosion resistance approximately equal to that of Type 316 stainless steel,* is not subject to intergranular corrosion due to carbides, or to stress corrosion cracking. It need not be heat-treated and quenched to obtain the desired corrosion resistance and in addition has a temperature expansion coefficient close to commercial steel plate. For these reasons, it can be used in a vessel of laminated shell construction at somewhat more economical cost than the solid alloy type of design. Corrosion rates vary somewhat in different zones of the vessel and at worst have not exceeded .012 inch per year for relatively short periods. The trend is a gradual reduction in rate with increased time of exposure. Corrosion products are primarily nickel compounds and tests indicate[10] that a modified Inconel of higher chromium content has somewhat better corrosion resistance, while welds in which 80-20 rod was used, because of possible iron dilution, show practically no attack. Inconel-clad steel plate construction also is being used in several such vessels.

Various low grade stocks run through the reaction vessel may have required a preliminary acid wash which, even with the utmost care in handling, may result in some mineral acidity in the feed stock. Where feed tanks of Type 316 stainless steel have been used to eliminate copper contamination, some trouble may result. Monel might be preferable from a corrosion standpoint, or the use of the recently

* See discussion at end of article.

introduced Carpenter 20 alloy tubing might be considered for heating coils where corrosion is the most rapid. Little or no corrosion has been observed in Inconel piping either on low or high pressure lines. Type 316 stainless steel lines have also been used, though consideration should be given to the possibility of carbon deposition when field welding these lines, where subsequent heat-treating is impractical.

Mineral acidity may be particularly active on Type 316 stainless steel and similar metals in pump and control valves at points where both high velocity flow and corrosion can occur. The type "20" alloys such as Durimet 20 and Aloyco 20, or the Hastelloys may be of some value in resisting corrosion, but frequently are not of sufficient hardness to resist erosion. The development of a hardenable alloy with corrosion resistance to hot fatty acid containing even as little as .01 percent of 10-30 percent H_2SO_4 in suspension would find numerous uses in this and other industries.

Several relatively new alloy developments[11,12,13,14] originally produced for jet engines, have compositions and hardenable characteristics which indicate possible usefulness in some of the above applications. Whether test samples have been used is not known but their trial would seem to be of considerable interest.

Author's Note

Since writing this paper, the use of Hastelloy "B" for control valve trim, on pressure splitter feed stock, containing suspended sulfuric acid, has been found to provide an average usable life of six months before replacement becomes necessary.

It also is of interest to report that in fatty acid service, in a special application, using temperatures of 600° F. and above, Type 316 stainless steel is satisfactory with liquid stocks at moderate velocities. However, in a zone of reduced pressure, where flashing of fatty acid, high velocity and turbulence occur, Type 316 is rapidly attacked, corrosion rates of as high as .0156 inch per month being observed.

References

1. Technical Bulletin T-18, International Nickel Co., Inc., New York, N. Y. (1940).
2. McBride, G. W., *Chem. Eng.*, **54**, No. 4, 134-5 (1947).
3. Editors, *Chem. Eng.*, **55**, No. 11, 103-4 (1948).
4. Editors, *Chem. Eng.*, **53**, No. 11, 133-4 (1946).
5. The Corrosion Handbook, John Wiley & Sons, Inc. (1948).
6. Marsel, C. J., Allen, H. D., *Chem. Eng.*, **54**, No. 6, 104-8 (1947).
7. Bulletin 2051, Blaw Knox Co., Pittsburgh, Pa. (1945).
8. Editors, *Chem. Eng.*, **53**, No. 11, 168 (1946).
9. Demmerle, R. L., *Ind. Eng. Chem.*, **39**, 126-131 (1947).
10. Emery Industries, A. O. Smith Corp., Joint tests.
11. Sweeney, W. O., *ASME Trans.*, **69**, 569-81 (1947).
12. Scott, H., Gordon, R. B., *ASME Trans.*, **69**, 583-91 (1947).
13. Ibid, **69**, 593-99 (1947).
14. Bulletin, "Alloys for High Temperature Service," Haynes Stellite Co., Kokomo, Ind. (1948).

DISCUSSION

Author's Comment:

I have stated that Inconel has an expansion coefficient close to commercial steel plate. In the verbal presentation it was stated that Inconel was preferred for multi-layer construction for this reason. In addition I stated that thickness of alloy sheet used in Smith spot weld lining process was limited to 5/64-inch, which seemed too thin for use on this type of vessel

Both these statements were questioned and corrected by Mr. M. A. Scheil of A. O. Smith Co.

Comment by M. A. Scheil, A. O. Smith Corporation, Milwaukee, Wis.:

The following are excerpts from a letter covering the points raised above by Mr. Paul:

"If I remember correctly you mentioned that 5/64th" thick lining was a limitation of the Smith spot welded lining process and also that the limitation of a protective alloy inner shell of a Smith layer built vessel required that the inner alloy shell material be of similar coefficient of expansion to that of the carbon steel wrapping. x x x x x 5/64th" thick linings were generally considered the lower limit of our thickness but x x 7/64th" and ⅛" are the nominal thicknesses used for the austenitic alloys and other high-alloy materials. Recently we have improved our process whereby we can attach Type 316 and Type 347 stainless steel linings up to 3/16" thickness by Smithlining methods.

With regard to your suggested limitation of the alloy materials for the inner shells of layer built vessels, (it is well to note) the design of the particular pilot vessel you described, x x because of the many openings through the layers to the inner shell, it was considered best to use the low coefficient of expansion material, Inconel, particularly since this material is satisfactory for fatty acid type corrosion. x x x x x we (have) built several layer vessels with a Type 316 and Type 347 alloy inner shell and x x all of these have been operated successfully—some as high as 500° F.

INDEX TO TECHNICAL MATERIAL

CORROSION

VOLUME 5

JAN. 1-DEC. 31

1949

CONTENTS

Contents Pages by Months
Technical Committee Activities
Technical Practices Committee Reports
Correlating Committee on Cathodic Protection
Titles, Alphabetically by First Indicative Word
Authors, Alphabetically
Corrosion Abstracts, Subjects, by Months, Pages

PAGE NUMBERS BY MONTHS

PAGES	
1- 37	January
39- 59	February
71- 98	March
101-134	April
135-168	May
169-201	June
203-244	July
245-271	August
273-313	September
315-354	October
355-377	November
379-450	December

CONTENTS PAGES BY MONTHS

January

Page

Behavior of Hydrogen in Steel During and After Immersion in Acid
By Lawrence S. Darken and Rodney P. Smith 1

Cathodic Protection Applied to Gas and Electric Utility Operations
By William J. Schreiner 17

Experience at Bagnell Dam to Prevent Corrosion of Underwater Steel and Iron
By Turner White, Jr. 25

Corrosion Problems in Water Wells
By T. E. Larson 27

Attenuation Equations Applied to Cathodic Protection by Distributed Drainage
By E. P. Doremus, G. L. Doremus and M. E. Parker, Jr. 32

Aluminum Valve Construction
By R. McFarland (Topic of the Month) 37

February

Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid
By W. E. Pratt and E. T. Collinsworth, Jr. 39

A Geographic Study of Deposits and Corrosion
By Dr. F. N. Alquist 45

Discussion on "Selected Bibliography on Salt Spray Testing"
By Lorraine R. Voigt, L. M. Flaherty 54

Errata: "Punched Cards for Filing Corrosion Test Results"
By Lorraine R. Voigt, Corrosion, Dec., 1948 54

Organic Linings for Chemical Equipment
By Kenneth Tator 55

Mitigation of Corrosion on City Gas Distribution Systems
By A. D. Simpson, Jr. 59

March

Unusual Corrosion in High Pressure Boilers
By S. T. Powell and R. G. Von Lossberg 71

A Cooperative Approach to Electrolysis Problems
By Russell M. Lawall 79

Galvanic Corrosion in Oil and Gas Well Fluids
By F. L. LaQue 86

Protective Films—Natural Formation on Aluminum and Its Alloys
By F. A. Champion 92

Combating Corrosion with Rubber Lining
By R. McFarland (Topic of the Month) 98

April

Effect of Various Aqueous Solutions Upon the Reactions at Pure Iron Anodes and Cathodes—Part I
By W. W. Kittleberger and A. C. Elm 101

Marine Fouling and Boring Organisms, With Some Material on Corrosion
By J. L. Baughman 113

Corrosion, Passivity and Passivation from the Thermodynamic Point of View
By M. Pourbaix 121

Errata: "Bearing Corrosion in Turbo-Generators" 133

Corrosion of Base Metal Contact Surfaces in the Telephone System
(Anonymous) (Topic of the Month) 134

May

Page

Crude Still Overhead System Corrosion
By A. F. Blumer 135

Building Organic Protective Coatings to Special Requirements
By K. G. Compton 148

A Case of Corrosion Involving Cinders
By C. H. Thompson 151

Effect of Various Aqueous Solutions Upon the Reactions at Pure Iron Anodes and Cathodes—Part II
By W. W. Kittelberger and A. C. Elm 155

Errata: By W. W. Kittelberger and A. C. Elm 200

Corrosion in Sour Crude Storage Tanks
By Derk Holsteyn (Topic of the Month) 168

June

Why Metals Corrode
By Dr. H. H. Uhlig 169
Discussion: Norman Hackerman, Lyle R. Sheppard, W. F. Gross, Page 352

Electrochemical Studies on Insulating Couplings For Underground Pipe and Cable Lines
By Dr. W. Beck 175

Corrosion Problems in a Fluid Catalytic Cracking and Fractionating Unit
By Nathan Schofer 182

Erosion-Corrosion of Metals and Alloys
By M. G. Fontana and W. A. Luce 189
Discussion: Harris Thompson, H. H. Bennett, James R. Harrison, Lewis P. Aker, H. O. Teeple, Page 376

Corrosion of Telephone Outside Plant Material
By K. C. Compton and A. Mendizza 194
Discussion: C. J. Couy, Page 350; J. M. Standring, Page 377

Methods for Prevention of Rust in Water Tanks—A Preliminary Report
By Fred Schumann 198
Discussion: J. L. Gilliland, Jr., Page 310

Errata: "Effect of Various Aqueous Solutions Upon The Reactions at Pure Iron Anodes and Cathodes"
By W. W. Kittelberger and A. C. Elm 200

Protection for Ship Hulls
By L. M. Mosher (Topic of the Month) 201

July

Corrosion Research in the Navy
By Julius J. Harwood and Fred Schulman 203

Special Anodes for the Cathodic Protection of Water Tanks
By A. L. Kimmel 217

Development of Pipe Line Coatings and Mechanical Application Methods
By Stephen D. Day 221

High Temperature Corrosion of Metals
By Andrew Dravnieks and Dr. Hugh J. McDonald 227

Principles of Writing Specifications for Metal Protective Paints
By W. W. Cranmer 234

The Role of Adsorption from Solution in Corrosion Inhibitor Action
By Dr. Norman Hackerman and Harold R. Schmidt 237

Destruction of An Admiralty Tube Bundle by Stress Corrosion in the Presence of Mercury
By B. B. Morton (Topic of the Month) 244

August

Page

Comparative Corrosion Resistance of Some Copper Alloy Condenser Tubes
By John R. Freeman, Jr., and A. W. Tracy 245

Practical Corrosion Control on Gas Transmission Lines
By G. R. Olson and H. V. Beezley 249

The Pulse Polarizer in Corrosion Technology
By Dr. Hugh J. McDonald and Glenn A. March 254
Discussion: F. I. LaQue, J. M. Bialosky, Page 350

Physical and Corrosion Characteristics of Lead in the Chemical Industry
By Kempton H. Roll 261

Application of Alloy Steel Linings to Tank Storing Corrosive Pulp Cooking Liquor
By H. A. Schmitz and M. A. Scheil (Topic of the Month) 271

September

Engineering Aspects of Cathodic Protection as Applied to Pipe Lines
By E. P. Doremus, G. L. Doremus and M. E. Parker, Jr. 273
Discussion: W. P. Noser, Page 351

Corrosion Resistance of Sprayed Metal Coatings
By Walter B. Meyer 282

An Investigation of Structural Steel Shop Coat Priming Paint
By S. C. Frye 288
Discussion: Dr. H. F. Haase, I. E. Boberg, E. W. Wallace, S. M. Gleser, Page 352

Cathodic Protection of Steel Piling in Sea Water
By H. A. Humble 292
Discussion: By G. C. Cox, Page 300. By C. P. Larrabee and L. F. LaQue, Page 301

Corrosion Testing Facilities at Kure Beach, North Carolina
By Ivy M. Parker 303

A Method for Activating Stainless Steel Specimens Prior to Corrosion Tests
By R. O. Bayer and E. A. Kachik 308

Discussion: Methods for Preventing Rust in Water Tanks
By J. L. Gilliland, Jr. 310

Multi-Layer Insulation Applications include Non-Capillary Glass Fabric
(Anonymous) (Topic of the Month) 313

October

The Use of Selenium Rectifiers as One-Way Valves In Electrolysis Drainage Wires
By W. D. Connon 315

Corrosion Resistance of Commercially Pure Titanium
By G. E. Hutchinson and P. H. Permar 319
Discussion: Fred W. Schmitz, Paul Gegner, Page 324; Dr. Mars Fontana, F. T. Wood, Jr., Tom R. Watson, B. B. Morton, Page 325

The Study of Corrosion in the Colleges
By Hugh J. McDonald 326

Electrochemical Behavior of Zinc and Steel in Aqueous Media
By R. B. Hoxeng and C. F. Prutton 330
Discussion: F. A. Prange, Page 338

Deterioration of Steel Sheet Pile Groins at Palm Beach, Florida
By Culbertson W. Ross 339

Technical Factors in Testing Pipe Line Coatings
By D. E. Stearns, M. W. Belson and R. H. Lee 342

A Note on the Effect of Variations of Exposed Area On Solution Potential and Corrosion Rate of Low Carbon Steel
By J. M. Bialosky 346
Discussion: J. Preston Engle, Page 349

High Speed Stress, Corrosion Tester
(Anonymous) (Topic of the Month) 354

DISCUSSIONS

Corrosion of Telephone Outside Plant Material: *C. J. Couy* 350

The Pulse Polarizer in Corrosion Technology:
F. L. LaQue, J. M. Bialosky 350

Engineering Aspects of Cathodic Protection as Applied to Pipe Lines: *W. P. Noser* 351

An Investigation of Structural Steel Shop Coat Priming Paint:
Dr. H. F. Haase, I. E. Boberg, E. W. Wallace, S. M. Gleser 352

Why Metals Corrode:
Norman Hackerman, Lyle R. Sheppard, W. F. Gross 352

November

Page

Corrosion Tests in the Processing of Soap and Fatty Acids
By W. Z. Friend and J. F. Mason, Jr. 355
Discussion: John L. McPherson, Page 367; M. A. Scheil, Page 368

Experience and Economic Benefits from Cathodic Protection on Gas Distribution Systems
By A. W. Peabody and C. L. Woody 369

Electrolytic Corrosion of Steel in Concrete
By G. M. Magee 378
Discussion: Sidney E. Trouard, Page 380; L. S. Brown, Page 381

Corrosion in Petroleum Processes Employing Aluminum Chloride
By R. S. Treseder and A. Wachter 383

Cooperative Corrosion Testing in the Wood Pulping Industry
By T. R. Gaulke and M. A. Scheil 392
Discussion: J. O. Shelby, Beaumont, Thomas, J. J. Heger, Page 401

Proper Bonding of Power Cable Sheath Guards Against Galvanic Corrosion
By W. D. Sanderson (Topic of the Month) 403

DISCUSSIONS

Erosion-Corrosion of Metals and Alloys: Harris Thompson, H. H. Bennett, James R. Harrison, Lewis P. Aker, H. O. Teeple 376

The Use of Selenium Rectifiers as One-Way Valves in Electrolysis Drainage Wires: M. M. Standring 377

December

The Behavior of Bituminous Pipe Coatings Under Bending Vibrational Stress
By Dr. W. Beck 405

Correlation Between Corrosion Survey Results and Actual Conditions as Determined Through 130 Miles Of Continuous Reconditioning
By I. B. Tietze 409
Discussion: R. J. Emerson, Page 414; J. C. Stirling, Page 415.

Cathodic Protection of Marine Tractor (Topic of the Month)
By Oliver Osborn 416

Marine Boiler Deterioration
By I. G. Slater and N. L. Parr 417

Corrosion Problems in the Pulp and Paper Industry
By Dr. Roy P. Whitney 435

Plant Corrosion in the Fatty Acid Industry
By R. J. Paul 439
Discussion: M. A. Scheil, Page 442.

Technical Committee Activities

Corrosion Problems in Handling and Processing Chemicals (April)
By M. G. Fontana viii

Extensive New Fields of Inquiry Are Considered by T. P. Committee 1 (May)
By W. F. Rogers xi

Interim Report Completed on Galvanic Anode Tests (June)
By M. C. Miller xi

Tests of Steel, Carbon and Graphite Anodes Now Are Under Way (July)
By M. A. Judah xi

Procedures Outlined For Cathodic Protection Minimum Current Data Experiments (Aug.)
By A. V. Smith xi

New Developments in Protective Coatings (Sept.)
By Kenneth Tator xv

Technical Information on Corrosion at Elevated Temperatures Sought (Oct.)
By M. A. Scheil xi

Improvement in Corrosion Inhibitors Science And Technology Is Aim of TP-9 (Dec.)
By A. Wachter xi

Technical Practices Committee Reports

(Sept.)
Sub-Committee T.P.-12—Electrical Grounding Practices (A-TP12) ... 311

Correlating Committee on Cathodic Protection

(Sept.)
Bulletin II—Cathodic Protection Notification Procedures 2
Bulletin IV—Joint Cathodic Protection Systems 7

TITLES, ALPHABETICALLY BY FIRST INDICATIVE WORD

A

Aluminum Valve Construction (Topic Of The Month) Jan.
R. McFarland 37

Application of Alloy Steel Linings to Tanks Storing Corrosion Pulp Cooking Liquor (Topic Of The Month) Aug.
H. A. Schmitz and M. A. Scheil 271

Attenuation Equations Applied to Cathodic Protection by Distributed Drainage Jan.
E. P. Doremus, G. L. Doremus and M. E. Parker 32

B

Bearing Corrosion In Turbo-Generators (Errata) Apr.
J. A. Ten Broeke 133

Behavior of Bituminous Pipe Coatings Under Bending Vibrational Stress Dec.
D. W. Beck 405

Behavior of Hydrogen in Steel During and After Immersion in Acid Jan.
Lawrence S. Darken and Rodney P. Smith 1

Building Organic Protective Coatings to Special Requirements May
K. G. Compton 148

C

Case of Corrosion Involving Cinders May
C. H. Thompson 151

Cathodic Protection Applied to Gas and Electric Utility Operations Jan.
William J. Schreiner 17

Cathodic Protection of Marine Tractor (Topic of the Month) Dec.
Oliver Osborn 416

Cathodic Protection of Steel Piling in Sea Water Sept.
H. A. Humble 292

Combating Corrosion With Rubber Lining (Topic of the Month) Mar.
R. McFarland 98

Comparative Corrosion Resistence of Some Copper Alloy Condenser Tubes Aug.
John R. Freeman, Jr., and A. W. Tracy 245

Cooperative Approach to Electrolysis Problems Mar.
Russell M. Lawall 79

Cooperative Corrosion Testing in the Wood Pulping Industry Nov.
T. R. Gaulke and M. A. Scheil 392

Correlation Between Corrosion Survey Results and Actual Conditions as Determined through 130 Miles of Continuous Reconditioning Dec.
I. B. Tietze 409

Corrosion in Petroleum Processes Employing Aluminum Chloride Nov.
R. S. Treseder and A. Wachter 383

Corrosion in Sour Crude Storage Tanks (Topic of the Month) May
Derk Holsteyn 168

Corrosion of Base Metal Contact Surfaces in the Telephone System (Topic of the Month) *Anonymous* Apr. 134

Corrosion of Telephone Outside Plant Material June
K. G. Compton and A. Mendizza 194
Discussion: C. J. Couy, 350.

Corrosion, Passivity and Passivation from the Thermodynamic Point of View Apr.
M. Pourbaix 121

Corrosion Problems in a Fluid Catalytic Cracking and Fractionating Unit June
Nathan Schofer 182

Corrosion Problems in the Pulp and Paper Industry Dec.
Dr. Roy P. Whitney 435

Corrosion Problems in Water Wells Jan.
T. E. Larson 27

Corrosion Research in The Navy July
Julius J. Harwood and Fred Schulman 203

Corrosion Resistance of Commercially Pure Titanium Oct.
G. E. Hutchinson and P. H. Permar 319

Corrosion Resistance of Sprayed Metal Coatings Sept.
Walter B. Meyer 282

Corrosion Testing Facilities at Kure Beach, North Carolina Sept.
Ivy M. Parker 303

Corrosion Tests in the Processing of Soap and Fatty Acids Nov.
W. Z. Friend and J. F. Mason, Jr. 355

Crude Still Overhead System Corrosion May
A. F. Blumer 135

D

Destruction of an Admiralty Tube Bundle By Stress Corrosion in the Presence of Mercury (Topic of the Month) July
B. B. Morton 224

Deterioration of Steel Sheet Pile Groins at Palm Beach, Fla. Oct.
Culbertson W. Ross 339

Development of Pipe Line Coatings and Mechanical Application Methods July
Stephen D. Day 221

E

Effect of Various Aqueous Solutions Upon the Reactions at Pure Iron Anodes and Cathodes
W. W. Kittelberger and A. C. Elm
Part I ..... (Apr.) 101
Part II ..... (May) 155
Errata ..... (June) 200

Electrochemical Behavior of Zinc and Steel in Aqueous Media Oct.
H. B. Hoxeng and C. F. Prutton 330

Electrochemical Studies on Insulating Couplings For Underground Pipe and Cable Lines June
W. Beck 175

Electrolytic Corrosion of Steel in Concrete Nov.
G. M. Magee 378

Engineering Aspects of Cathodic Protection As Applied to Pipe Lines Sept.
E. P. Doremus, G. L. Doremus, and M. E. Parker, Jr. 273
Discussion: W. P. Noser, 351.

Erosion-Corrosion of Metals and Alloys June
M. G. Fontana and W. A. Luce 182
Discussion: Harris Thompson, H. H. Bennett, James R. Harrison, Lewis P. Aker, H. O. Teeple, 376.

Experience and Economic Benefits from Cathodic Protection on Gas Distribution Systems Nov.
A. W. Peabody and C. L. Woody 369

Experience at Bagnell Dam to Prevent Corrosion of Underwater Steel and Iron Jan.
Turner White, Jr. 25

G

Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid — Feb. 39
W. E. Pratt and E. T. Collinsworth, Jr.

Galvanic Corrosion in Oil and Gas Well Fluids — Mar. 86
F. L. LaQue

Geographic Study of Deposits and Corrosion — Feb. 45
F. N. Alquist

H

High Speed Stress, Corrosion Tester (Topic of the Month) — Oct. 354
Anonymous

High Temperature Corrosion of Metals — July 227
Andrew Dravnieks and Dr. Hugh J. McDonald

I

Investigation of Structural Steel Shop Coat Priming Paint — Sept. 288
S. C. Frye
Discussion: H. F. Haase, I. E. Boberg, E. W. Wallace, S. M. Gleser, 352.

M

Marine Boiler Deterioration — Dec. 417
I. G. Slater and N. L. Parr

Marine Fouling and Boring Organisms, With Some Material on Corrosion — Apr. 113
J. L. Baughman

Method for Activating Stainless Steel Specimens Prior to Corrosion Tests — Sept. 308
R. O. Bayer and E. A. Kachik

Methods for Prevention of Rust In Water Tanks—A Preliminary Report — June 198
Fred Schumann
Discussion: J. L. Gilliland, Jr., 310.

Mitigation of Corrosion on City Gas Distribution Systems — Feb. 59
A. D. Simpson, Jr.

Multi-Layer Insulating Applications Include Non-Capillary Glass Fabric (Topic of the Month) — Sept. 313
Anonymous

N

Note on the Effect of Variations of Exposed Area on Solution Potential And Corrosion Rate of Low Carbon Steel — Oct. 346
J. M. Bialosky

O

Organic Linings for Chemical Equipment — Feb. 55
Kenneth Tator

P

Physical and Corrosion Characteristics of Lead in the Chemical Industry — Aug. 261
Kempton H. Ross

Plant Corrosion in the Fatty Acid Industry — Dec. 439
R. J. Paul

Practical Corrosion Control On Gas Transmission Lines — Aug. 249
G. R. Olson and H. V. Beezley

Principles of Writing Specifications for Metal Protective Paints — July 234
W. W. Cranmer

Proper Bonding of Power Cable Sheath Guards Against Galvanic Corrosion (Topic of the Month) — Nov. 403
W. D. Sanderson

Protection for Ship Hulls (Topic of the Month) — June 201
L. M. Mosher

Protective Films—Natural Formation on Aluminum and Its Alloys — Mar. 92
F. A. Champion

The Pulse Polarizer in Corrosion Technology — Aug. 254
Hugh J. McDonald and Glenn A. Marsh
Discussion: F. L. LaQue, J. M. Bialosky, 350.

Punched Cards for Filing Corrosion Test Results (Errata) — Feb. 54
Lorraine R. Voigt

R

Role of Adsorption From Solution in Corrosion Inhibitor Action — Jul. 237
Norman Hackerman and Harold R. Schmidt

S

Selected Bibliography on Salt Spray Testing (Discussion) — Feb. 254
L. M. Flaherty

Special Anodes for the Cathodic Protection of Water Tanks — July 217
A. L. Kimmel

Study of Corrosion in the Colleges — Oct. 326
Hugh J. McDonald

T

Technical Factors in Testing Pipe Line Coatings — Oct. 342
D. E. Stearns, M. W. Belson, and R. H. Lee

U

Use of Selenium Rectifiers as One-Way Valves in Electrolysis Drainage Wires — Oct. 315
W. D. Cannon
Discussion: J. M. Standring, 377.

Unusual Corrosion in High Pressure Boilers — Mar. 71
S. T. Powell and R. G. Von Lossberg

W

Why Metals Corrode — June 169
H. H. Uhlig
Discussion: Norman Hackerman, Lyle R. Sheppard, W. F. Gross, 352.

AUTHORS ALPHABETICALLY

A

AKER, LEWIS P. Nov.
Discussion—Erosion-Corrosion of Metals and Alloys 376

ALQUIST, F. N., DR. Feb.
A Geographic Study of Deposits and Corrosion 45

ANONYMOUS
Corrosion of Base Metal Contact Surfaces in the Telephone System (Topic of the Month) ..... (Apr.) 134
Multi-Layer Insulation Applications Include Non-Capillary Glass Fabric (Topic of the Month) ..... (Sept.) 313
High Speed Stress, Corrosion Tester (Topic of the Month) .. (Oct.) 354

B

BAUGHMAN, J. L. Apr.
Marine Fouling and Boring Organisms, With Some Material on Corrosion 113

BAYER, R. O. Sept.
A Method for Activating Stainless Steel Specimens Prior to Corrosion Tests. With E. A. Kachik 308

BECK, W., DR.
Electrochemical Studies on Insulating Couplings For Underground Pipe and Cable Lines ..... (June) 175
The Behavior of Bituminous Pipe Coatings Under Bending Vibrational Stress ..... (Dec.) 405

BEEZLEY, H. V. Aug.
Practical Corrosion Control on Gas Transmission Lines. With G. R. Olson 249

BELSON, M. W. Oct.
Technical Factors in Testing Pipe Line Coatings. With D. E. Stearns and R. H. Lee 324

BENNETT, H. H. Nov.
Discussion—Erosion-Corrosion of Metals and Alloys 376

BIALOSKY, J. M.
Note on the Effect of Variations of Exposed Area on Solution Potential and Corrosion Rate of Low Carbon Steel ..... (Oct.) 346
Discussion—The Pulse Polarizer in Corrosion Technology .. (Oct.) 350

BLUMER, A. F. May
Crude Still Overhead System Corrosion 135

BOBERG, I. E. Oct.
Discussion—An Investigation of Structural Steel Shop Coat Priming Paint 352

BROWN, L. S. Nov.
Discussion—Electrolytic Corrosion of Steel in Concrete 381

C

CHAMPION, F. A. Mar.
Protective Films-Natural Formation on Aluminum and Its Alloys .. 92

COLLINSWORTH, E. T., JR. Feb.
Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid. With W. E. Pratt 39

COMPTON, K. G.
Building Organic Protective Coatings to Special Requirements ..... (May) 148
Corrosion of Telephone Outside Plant Material. With A. Mendizza—Discussion: 350 ..... (Jun.) 194

CANNON, W. D. Oct.
Use of Selenium Rectifiers as One-Way Valves in Electrolysis Drainage Wires 315
Discussion: 377

COUY, C. J. Oct.
Discussion—Corrosion of Telephone Outside Plant Material 350

COX, GEORGE C. Sept.
Discussion—Cathodic Protection of Steel Piling in Sea Water 300

CRANMER, W. W. July
Principles of Writing Specifications for Metal Protective Paints .. 234

D

DARKEN, LAWRENCE S. Jan.
Behavior of Hydrogen in Steel During and After Immersion in Acid. With Rodney P. Smith 1

DAY, STEPHEN D. July
Development of Pipe Line Coatings and Mechanical Application Methods 224

DOREMUS, E. P.
Attention Equations Applied to Cathodic Protection by Distributed Drainage. With G. L. Doremus, and M. E. Parker, Jr. (Jan.) 32
Engineering Aspects of Cathodic Protection as Applied to Pipe Lines. With G. L. Doremus and M. E. Parker, Jr. ..... (Sept.) 272
Discussion: 351.

DOREMUS, G. L.
Attenuation Equations Applied to Cathodic Protection by Distributed Drainage. With E. P. Doremus, and M. E. Parker, Jr. .. (Jan.) 32
Engineering Aspects of Cathodic Protection as Applied to Pipe Lines. With E. P. Doremus and M. E. Parker, Jr. ..... (Sept.) 273
Discussion: 351.

DRAVNIEKS, ANDREW Jul.
High Temperature Corrosion of Metals. With Hugh J. McDonald 227

E

ELM, A. C.
Effect of Various Aqueous Solutions Upon the Reactions at Pure Iron Anodes and Cathodes. With W. W. Kittelberger.
Part I ..... (Apr.) 101
Part II ..... (May) 155
Errata: P. 200.

EMERSON, R. J. Dec.
Discussion—Correlation Between Corrosion Survey Results and Actual Conditions As Determined Through 130 Miles of Continuous Reconditioning 414

ENGLE, J. PRESTON Oct.
Discussion—Note on the Effect of Variations of Exposed Area on Solution Potential and Corrosion Rate of Low Carbon Steel 349

F

FLAHERTY, L. M. Feb.
Discussion—Selected Bibliography on Salt Spray Testing. (See Vol. 4, No. 10, 492-500 (1948) Oct.) 54

FONTANA, M. G.
Erosion-Corrosion of Metals and Alloys. With W. A. Luce .. (Jun.) 189
Discussion: P. 376.
Discussion—Corrosion Resistance of Commercially Pure Titanium ..... (Oct.) 325

FREEMAN, JOHN R., JR. Aug.
Comparative Corrosion Resistance of Some Copper Alloy Condenser Tubes. With A. W. Tracy 245

FRIEND, W. Z. Nov.
Corrosion Tests in the Processing of Soap and Fatty Acids. With J. F. Mason, Jr. 355
Discussion: P. 367, 368.

FRYE, S. C. Sept.
An Investigation of Structural Steel Shop Coat Priming Paint 288
Discussion: P. 352.

G

GAULKE, T. R. Nov.
Cooperative Corrosion Testing in the Wood Pulp Industry 392
Discussion: P. 401.

GEGNER, PAUL Oct.
Discussion—Corrosion Resistance of Commercially Pure Titanium 324

GILLILAND, J. L., JR. Sept.
Discussion—Methods for Prevention of Rust in Water Tanks—A Preliminary Report 310

GLESER, S. M. Oct.
Discussion—An Investigation of Structural Steel Shop Coat Priming Paint 352

GROSS, W. F. Oct.
Discussion—Why Metals Corrode 352

H

HAASE, DR. H. F. Oct.
Discussion—An Investigation of Structural Steel Shop Coat Priming Paint 352

HACKERMAN, DR. NORMAN
The Role of Adsorption from Solution in Corrosion Inhibitor Action. With Harold R. Schmidt ..... (July) 237
Discussion—Why Metals Corrode ..... (Oct.) 352

HARRISON, JAMES R. Nov.
Discussion—Erosion-Corrosion of Metalsa nd Alloys ... 376
HARWOOD, JULIUS J. July
Corrosion Research in the Navy. With Fred Schulman ... 203
HEGER, J. J. Nov.
Discussion—Cooperative Corrosion Testing in the Wood Pulping Industry ... 401
HOLSTEYN, DERK May
Corrosion in Sour Crude Storage Tanks (Topic of Month) ... 168
HOXENG, R. B. Oct.
Electrochemical Behavior of Zinc and Steel in Aqueous Media. With C. F. Prutton ... 330
HUMBLE, H. A. Sept.
The Cathodic Protection of Steel Piling in Sea Water ... 292
Discussion: P. 301-302.
HUTCHINSON, G. E. Oct.
Corrosion Resistance of Commercially Pure Titanium. With P. H. Permar ... 319

K

KACHIK, E. A. Sept.
A Method for Activating Stainless Steel Specimens Prior to Corrosion Tests. With R. O. Bayer ... 308
KIMMEL, A. L. July
Special Anodes for the Cathodic Protection of Water Tanks ... 217
KITTELBERGER, W. W.
Effect of Various Aqueous Solutions Upon the Reactions at Pure Iron Anodes and Cathodes. With A. C. Elm.
Part I ... (Apr.) 101
Part II ... (May) 155
Errata P. 200.

L

LARRABEE, C. P. Sept.
Discussion—Cathodic Protection of Steel Piling in Sea Water ... 301
LARSON, T. E. Jan.
Corrosion Problems in Water Wells ... 27
LA QUE, F. L.
Galvanic Corrosion in Oil and Gas Well Fluids ... (May) 86
Discussion—Cathodic Protection of Steel Piling in Sea Water ... (Sept.) 301
Discussion—The Pulse Polarizer in Corrosion Technology ... (Oct.) 350
LAWALL, RUSSELL M. Mar.
Cooperative Approach to Electrolysis Problems ... 79
LEE, R. H. Oct.
Technical Factors in Testing Pipe Line Coatings. With D. E. Stearns and M. W. Belson ... 342
LUCE, W. A. June
Erosion-Corrosion of Metals and Alloys. With M. G. Fontana ... 189
Discussion: P. 376.

M

McDONALD, HUGH J.
High Temperature Corrosion of Metals. With Andrew Dravnieks ... (Jul.) 227
The Pulse Polarizer in Corrosion Technology. With Glenn A. Marsh ... (Aug.) 254
Discussion: P. 350.
Study of Corrosion in the Colleges ... (Oct.) 326
McFARLAND, R.
Aluminum Valve Construction. (Topic of the Month) ... (Jan.) 37
Combating Corrosion with Rubber Lining (Topic of the Month) ... (May) 98
McPHERSON, JOHN L. Nov.
Discussion—Corrosion Tests in the Processing of Soap and Fatty Acids ... 367
MAGEE, G. M. Nov.
Electrolytic Corrosion of Steel in Concrete ... 378
Discussion: 380, 381.
MARSH, GLENN A. Aug.
The Pulse Polarizer in Corrosion Technology. With Hugh J. McDonald ... 254
Discussion: P. 350.
MASON, J. F., JR. Nov.
Corrosion Tests in the Processing of Soap and Fatty Acids. With W. Z. Friend ... 355
Discussion: P. 367-368.
MENDIZZA, A. June
Corrosion of Telephone Outside Plant Material. With K. G. Compton ... 194
Discussion: P. 350.
MEYER, WALTER B. Sept.
Corrosion Resistance of Sprayed Metal Coatings ... 282
MORTON, B. B.
Destruction of an Admirality Tube Bundle by Stress Corrosion in The Presence of Mercury (Topic of Month) ... (July) 244
Discussion—Corrosion Resistance of Commercially Pure Titanium ... (Oct.) 325
MOSHER, L. M. June
Protection for Ship Hulls (Topic of the Month) ... 201

N

NOSER, W. P. Oct.
Discussion—Engineering Aspects of Cathodic Protection as Applied to Pipe Lines ... 351

O

OLSON, G. R. Aug.
Practical Corrosion Control on Gas Transmission Lines. With H. V. Beezley ... 249
OSBORN, OLIVER Dec.
Cathodic Protectiono f Marine Tractor (Topic of the Month) ... 416

P

PARKER, IVY M. Sept.
Corrosion Testing Facilities at Kure Beach, North Carolina ... 303
PARKER, M. E., JR.
Attenuation Equations Applied to Cathodic Protection by Distributed Drainage. With E. P. Doremus, and G. L. Doremus ... (Jan.) 32
Engineering Aspectso f Cathodic Protection as Applied ot Pipe Lines. With E. P. Doremus, and G. L. Doremus ... (Sept.) 273
Discussion: P. 351.
PARR, N. L. Dec.
Marine Boiler Deterioration. With I. G. Slater ... 417
PAUL, R. J. Dec.
Plant Corrosion in the Fatty Acid Industry ... 439
Discussion: P. 442
PEABODY, A. W. Nov.
Experience and Economic Benefits from Cathodic Protection on Gas Distribution Systems. With C. L. Woody ... 369
PERMAR, P. H. Oct.
Corrosion Resistance of Commercially Pure Titanium. With G. E. Hutchinson ... 319
POURBAIX, M. Apr.
Corrosion, Passivity and Passivation from the Thermodynamic Point of View ... 121
POWELL, S. T. Mar.
Unusual Corrosion in High Pressure Boilers. With Von Lossberg, R. G. ... 71
PRANGE, F. A. Oct.
Discussion—Electrochemical Behavior of Zinc and Steel in Aqueous Media ... 338
PRATT, W. E. Feb.
Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid. With Collinsworth, E. T., Jr. ... 39
PRUTTON, C. F. Oct.
Electrochemical Behavior of Zinc and Steel in Aqueous Media. With R. B. Hoxeng ... 330

R

ROLL, KEMPTON H. Aug.
Physical and Corrosion Characteristics of Lead in the Chemical Industry ... 261
ROSS, CULBERTSON W. Oct.
Deterioration of Steel Sheet Pile Groins at Palm Beach, Florida ... 339

S

SANDERSON, W. D. Nov.
Proper Bonding of Power Cable Sheath Guards Against Galvanic Corrosion. (Topic of the Month) 403

SCHEIL, M. A.
Application of Alloy Steel Linings to Tanks Storing Corrosive Pulp Cooking Liquor. (Topic of the Month.) With H. A. Schmitz (Aug.) 271
Discussion—Corrosion Tests in the Processing of Soap and Fatty Acids. (Nov.) 368
Cooperative Corrosion Testing in the Wood Pulping Industry. With T. R. Gaulke (Nov.) 392
Discussion: P. 401
Discussion—Plant Corrosion in the Fatty Acid Industry (Dec.) 442

SCHMITZ, FRED W. Oct.
Discussion—Corrosion Resistance of Commercially Pure Titanium 324

SCHMIDT, HAROLD R. Jul.
The Role of Adsorption from Solution in Corrosion Inhibitor Action. With Dr. Norman Hackerman 237

SCHMITZ, H. A. Aug.
Application of Alloy Steel Linings ot Tanks Storing Corrosive Pulp Cooking Liquor. (Topic of the Month.) With M. A. Scheil 271

SCHOFER, NATHAN June
Corrosion Problems in a Fluid Catalytic Cracking and Fractionating Unit 182

SCHREINER, WILLIAM J. Jan.
Cathodic Protection Applied to Gas and Electric Utility Operations 17

SCHULMAN, FRED Jul.
Corrosion Research in the Navy. With Julius J. Harwood 203

SCHUMANN, FRED Jun.
Methods for Prevention of Rust in Water Tanks—A Preliminary Report 198
Discussion: P. 310.

SHELBY, J. O. Nov.
Discussion—Cooperative Corrosion Testing in the Wood Pulping Industry 401

SHEPPARD, LYLE R. Oct.
Discussion—Why Metals Corrode 352

SIMPSON, A. D., JR. Feb.
Mitigation of Corrosion on City Gas Distribution Systems 59

SLATER, I. G. Dec.
Marine Boiler Deterioration. With N. L. Parr 417

SMITH, RODNEY P. Jan.
Behavior of Hydrogen in Steel During and After Immersion in Acid. With Lawrence S. Darken 1

STANDRING, J. M. Nov.
Discussion—The Use of Selenium Rectifiers as One-Way Valves in Electrolysis Drainage Wires 377

STEARNS, D. E. Oct.
Technical Factors in Testing Pipe Line Coatings. With M. W. Belson and R. H. Lee 324

STIRLING, J. C. Dec.
Discussion—Correlation Between Corrosion Survey Results and Actual Conditions as Determined Through 130 Miles of Continuous Reconditioning 415

T

TATOR, KENNETH Feb.
Organic Linings for Chemical Equipment 55

TEMPLE, H. O. Nov.
Discussion—Erosion-Corrosion of Metals and Alloys 376

TEN BROEKE, J. A. Apr.
Errata: Bearing Corrosion in Turbo-Generators (See Vol. 4, No. 12, P. 590 (1948) Dec.) 133

THOMAS, BEAUMONT Nov.
Discussion—Cooperative Corrosion Testing in the Wood Pulping Industry 401

THOMPSON, C. H. May
A Case of Corrosion Involving Cinders 151

THOMPSON, HARRIS Nov.
Discussion—Erosion-Corrosion of Metals and Alloys 376

TIETZE, I. B. Dec.
Correlation Between Corrosion Survey Results and Actual Conditions as Determined Through 130 Miles of Continuous Reconditioning 409
Discussion: P. 414, 415.

TRACY, A. W. Aug.
Comparative Corrosion Resistance of Some Copper Alloy Condenser Tubes. With John R. Freeman, Jr. 245

TRESEDER, R. S. Nov.
Corrosion in Petroleum Processes Employing Aluminum Chloride. With A. Wachter 383

TROUARD, SIDNEY E. Nov.
Discussion—Electrolytic Corrosion of Steel in Concrete 380

U

UHLIG, H. H. DR. Jun.
Why Metals Corrode 169
Discussion: P. 352.

V

VOIGT, LORRAINE R. Feb.
Errata: Punched Cards for Filing Corrosion Test Results (See Vol. 4, No. 12, 582-589 (1948) Dec.) 54

VON LOSSBERG, R. G. Mar.
Unusual Corrosion in High Pressure Boilers. With S. T. Powell 71

W

WACHTER, A. Nov.
Corrosion in Petroleum Processes Employing Aluminum Chloride. With R. S. Treseder 383

WALLACE, E. W. Oct.
Discussion—An Investigation of Structural Steel Shop Coat Priming Paint 352

WATSON, TOM R. Oct.
Discussion—Corrosion Resistance of Commercially Pure Titanium 325

WHITE, TURNER, JR. Jan.
Experience at Bagnell Dam to Prevent Corrosion of Underwater Steel and Iron 25

WHITNEY, ROY P. Dec.
Corrosion Problems in the Pulp and Paper Industry 435

WOOD, F. T., JR. Oct.
Discussion—Corrosion Resistance of Commercially Pure Titantium 325

WOODY, C. L. Nov.
Experience and Economic Benefits from Cathodic Protection on Gas Distribution Systems. With A. W. Peabody 369

CORROSION ABSTRACTS—SUBJECTS, BY MONTHS, PAGES

Subject Index to Abstracts on Corrosion Literature—Volume 5, 1949

SUBJECT	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Atmospheric	..	9	..	8	..	10	..	10	..	14	..	13
Bearing	..	9	..	..	20	12	9	10	..	14	..	..
Cathodic Protection	..	9	..	12	..	12	..	12	..	16	..	14
Chemical	18	10	27	..	20	12	..	20	..	18	18	..
Coatings	5	12	22	14	24	16	9	12	16	20	..	..
Condensate Wells	..	15	..	..	18	..	..	25	..	..	..	..
Construction Material	21	16	27	19	28	27	..	25	..	23	20	16
Fundamentals	21	21	..	..	..	30	18	28	16	..	23	..
General	22	..	27	18	30	34	..	..	24	..	24	..
Inhibitors	23	20	..	..	31	36	..	29	28	24	30	..
Inspection	23	21	..	..	32	38	..	29	32	25	..	..
Metal Failure	24	..	30	20	..	38	..	29	37	25	..	..
Oil Well	..	15	..	..	..	..	..	..	..	..	..	..
Pipe Line	..	..	..	..	..	41	..	..	..	..	..	..
Refinery	..	..	..	20	..	41	..	32	..	26	30	..
Surface Preparation	..	..	30	22	..	42	..	32	..	26	32	18
Testing	..	18	34	..	33	43	..	36	..	..	..	20
Underground	..	..	35	24	..	..	..	38	..	..	..	..
Water	26	..	36	26	..	..	..	38	..	..	..	20

NACE News

New NACE Section Is Organized in Baltimore

Tulsa Section's Plans to Hold Short Course On Corrosion During February Nearly Ready

Plans have been virtually completed by the Tulsa Section, NACE, for a short course on corrosion to be held during February at Tulsa, according to John W. Elder, secretary-treasurer. Bob Bullock, Interstate Oil Pipe Line Co., has named a committee to make arrangements for the course.

Mr. Bullock reported at the October 24 section meeting at the Tulsa Hotel that Mr. E. P. Doremus of Cathodic Protection Service, Houston, will discuss anodes; Mr. William E. Huddleston of Huddleston Engineering Co., Bartlesville, Okla., will discuss rectifiers and Mr. Gaines Laster, Tulsa Pipe Coating Co., will discuss coatings. L. A. Hugo, Phillips Petroleum Co., Bartlesville, Okla., reported 35 members interested in the cathodic protection phase, 30 in the pipe line coating phase and approximately 20 in testing. Only two companies reported they were not interested, he said. Preference for the course to be held in three sessions was indicated also, rather than in one long session.

October Meeting

During the session Mr. Bullock reviewed a paper delivered by J. A. Holloway at the Dallas Regional meeting, after which there was a round-table discussion regarding the use of expendable anodes for spot protection of pipe lines. During this discussion Earl W. Unruh, Sinclair Refining Co., Independence, Kan., said his company was embarking on a program of anode installation. I. B. Tietze, Phillips Petroleum Co., Bartlesville, chairman of the section, requested Mr. Unruh to prepare a talk a year from now giving his experience.

The concensus at the close of the round table session was that general practice consists of using one to three anodes per pit leak. For general repairs, anodes should be spaced at 50-foot intervals through the length of the reconditioned pipe.

Tour Resume Given

Jack Barrett of Stanolind Oil and Gas Co. gave a resume of the Permian Basin Section's corrosion tour. He said the tour was about the same as last year with the same findings.

Dr. F. T. Gardner of University of Tulsa gave a resume of the paper "Control of Vapor Zone Corrosion in Storage Tanks by the Use of Ammonia," which was presented originally at the Dallas NACE Regional meeting.

Jim Hunter of Stanolind Pipe Line Company discussed a method of coating pipe line internally with a plastic.

Forty attended the July 25 meeting of the section at Mohawk Park. Baseball was played and after a round of horseshoes, dinner was enjoyed.

NACE MEMBERS

IF You Change Addresses

IF You Change Company Affiliation

IF You Change Positions

Please notify the Central Office NACE, 919 Milam Building, Houston 2, Texas, so that you will get CORROSION without delay and that association records can be kept abreast of your progress.

THANKS!

All But 18 Conference Booths Have Been Taken

As of Monday, November 14, all but 18 of the 77 booths available for the exposition to be held concurrently with the 1950 Conference of the National Association of Corrosion Engineers at Hotel Jefferson, St. Louis, April 4-7, have been sold. Forty-six organizations from all over the United States have requested space.

The following list of firms reserving space is supplementary to that published in the November issue:

Aluminum Co. of America, Pittsburgh, Pa.

American Pipe and Construction Co., Amercoat Div., Chicago, Ill.

Cathodic Protection Service, Houston, Texas.

Dow Chemical Co., Midland, Mich.

National Lead Co., New York, N. Y.

Tinker and Rasor, San Gabriel, Cal.

Tretolite Co., Webster Groves, Mo.

U. S. Stoneware Co., Akron, Ohio.

T. D. Williamson Co., Tulsa, Okla.

Thirty-one members and guests were present for the first meeting of the newly-organized Baltimore Section NACE at Park Plaza Hotel, Baltimore, November 1. The date was selected to accommodate members of the Transmission and Distribution Committee of the Edison Electric Institute in session in the city at that time. Nine men from the group attended.

A. B. Campbell, NACE executive-secretary, who was present for the meeting, told of the association's interest in developing local section programs to provide an interchange of experience and ideas on corrosion problems and offered assistance of Central Office to that end.

Dr. I. A. Denison, Chief, Underground Corrosion, Division of Metallurgy, National Bureau of Standards, spoke on the topic "The Effect of Properties of Soils on the Corrosion of Materials of Construction Underground." Dr. Denison explained the prime importance of aeration as a controlling factor in determining the corrosivity of soils, and showed slides of low carbon steel, copper, lead and zinc specimens exposed underground in various typical soils throughout the country. The relation between good drainage characteristics and relatively low corrosion rates was apparent.

The following were elected officers of the section:

Edgar F. Wolf, Consolidated Gas Electric Light and Power Co. of Baltimore, chairman; Homer D. Holler, National Bureau of Standards, Washington, D. C., vice-chairman; George E. Best, Mutual Chemical Co. of America, secretary-treasurer.

Transportation Symposium Co-Chairmanship Taken

Merritt A. Williamson, Research and Development Dept., Pullman-Standard Car Manufacturing Co., Hammond, Ind., has accepted appointment as co-chairman of the Transportation Industry Symposium for the 1950 NACE Conference in St. Louis, Mo., April 4-7.

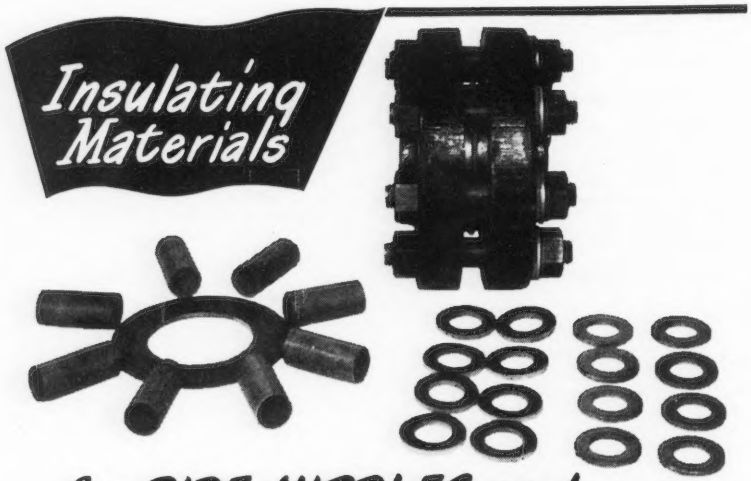
Changes in officers, or changes in addresses of officers should be brought to the attention of Central Office by secretaries of NACE regions and sections. Changes will be made as soon as possible in the monthly list "Directory of Regional and Sectional Officers."

14 Papers Tentatively Scheduled for St. Louis

Philadelphia Section's December Meeting Is Changed to Twelfth

Philadelphia Section has changed its December meeting date from the 13th to the 12th. The meeting, scheduled for the Engineers Club of Phildelphia, 1317 Spruce Street, Philadelphia, Pa., will begin with dinner at 6:30 p.m., after which a business meeting will be held beginning at 7:30 p.m.

Scheduled program includes an informal discussion led by qualified speakers on the following subjects: Natural and synthetic rubber linings for handling corrosives; application of aluminum heat exchanger tubes to corrosive conditions and Teflon coating of steel. Discussion subjects are designed to be of general interest to industry, particularly that on Teflon, a new development about which little is now known.



for PIPE NIPPLES and PIPELINE FLANGES

WRITE FOR VALUABLE, NEW BULLETIN

For a period of 10 years the Nelson Electric Manufacturing Company has been furnishing Phenolic Insulating Materials for pipe nipples and the insulation of pipeline flanges. We introduced the use of thin-wall tubing sleeves for insulating the studs in standard flanges, without requiring re-drilling of the flange and providing smaller studs. We now offer flange insulation, packaged for immediate shipment on the more common sizes.

Write for new, 10-page bulletin which describes our Insulating Materials.

NELSON Electric MANUFACTURING CO.

217 N. Detroit St. TULSA, OKLAHOMA Telephone 2-5131

Manufacturers of: Explosion Proof Motor Controls, Junction Boxes and Enclosures, Circuit Breakers and Lighting Panels, Oil Field Motor Controls, Automatic Pipe Line Sampling Devices, Cathodic Protection Equipment, Switchboards, Instrument and Control Panels, Unit Substations.

Information released by Dr. Aaron Wachter, chairman of the 1950 NACE Conference technical program committee shows the following arrangements have been made tentatively for papers in the nine symposia:

Corrosion Principles

"Influence of Stress on Corrosion," by J. Harwood, Office of Naval Research, Washington, D. C.

Transportation Industry

"Water-side Corrosion of Diesel Engine Cylinder Liners," by F. L. LaQue, The International Nickel Co., Inc., New York, and F. N. Speller, Consulting Engineer, Pittsburgh, Pa.

Fresh and Salt Water

"Merits of Protection in Fresh Waters," by J. A. Davenport, Corps of Engineers, Cincinnati, Ohio.

"Galvanic Relationship Between Zinc and Steel," by R. B. Hoxeng, Case Institute of Technology, Cleveland, Ohio.

Protective Coatings

"Techniques of Surface Preparation and Economics Thereof," by A. Liebman, Dravo Corp., Pittsburgh, Pa.

"A Study of Paint Coatings and Cathodic Protection," by L. P. Sudrabin, Electro Rust-Proofing Corp., Belleville, N. J., and A. J. Eickhoff, National Lead Co., New York.

Prepared discussion by two or three authors on subject of paper by Sudrabin and Eickhoff.

Cathodic Protection

"Cathodic Protection of Ships," by G. L. Christie, Naval Research Establishment, Halifax, Canada.

"Design of Anode Systems for Cathodic Protection of Underground and Water Submerged Metallic Structures," by E. R. Shepard and H. J. Graeser, Department of the Army, Washington, D. C.

"Performance of Magnesium Galvanic Anodes," by H. A. Robinson and O. Osborn, Dow Chemical Co., Midland, Mich.

Chemical Industry

"Phosphoric Acid Corrosion," by F. P. LaBelle, Monsanto Chemical Co., St. Louis, Mo.

"Behavior of Stainless Steel in Sulfuric Acid," by W. R. Renshaw, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Oil and Gas Industry

"Corrosion in Condensate and High Pressure Sweet Oil Wells," by R. C. Buchan, Humble Oil and Refining Co., Houston, Texas.

"Corrosion of Steel in Natural Gas Containing Hydrogen Sulphide at Elevated Pressure and Temperature," by Dr. A. V. Metler, Field Research Laboratories, Magnolia Petroleum Co., Dallas, Texas.

"The Use of Formaldehyde as a Corrosion Inhibitor in Oil Wells," by Jack P. Barrett, Stanolind Oil and Gas Company, Tulsa, Okla.

Four Papers Are Presented at North East Region Pittsburgh Section Joint Meeting October 20

Four technical papers and a motion picture on the construction of offshore drilling platforms featured the joint meeting October 20 at the William Penn Hotel, Pittsburgh, Pa., of the North East Region and the newly-formed Pitetsburgh Section. There was a cocktail hour and a dinner.

Technical papers presented were:

"Service Analysis of Surface Preparation and Paint Application Economics," by A. J. Liebman, Dravo Corp.

"Corrosion Problems in the Modern By-Product Coke Plant," by C. F. Pagacar, Mellon Institute.

"Scientific Approach to Municipal Water Corrosion," by V. V. Kendall, National Tube Co.

"A Birdseye View of Corrosion Problems," by N. P. Peifer, Manufacturers' Light and Heat Co.

Following the cocktail hour a dinner was held with Basil H. Lucas of the Benedum Trees Oil Co., as the speaker. Mr. Lucas showed motion pictures depicting construction and operation of off-shore drilling platforms in the Gulf of Mexico.

Expenses of the meeting and the cocktail hour were sponsored by the following companies: Aluminum Company of America, Calgon, Inc., Carnegie-Illinois Steel Corp., Federated Metals Div., American Smelting and Refining Co., Inc., Bergen, N. J.; General Paint Corp., Cleveland, Ohio; Midwest Engine and Equipment Co., Tulsa, Okla.; Moraine Construction Co., Youngstown, Ohio; National Tube Co., Richard H. Peifer Co., Carnegie, Pa.; Pipe Protection Service, Inc., Elizabeth, N. J.; Pittsburgh Coke & Chemical Co., H. C. Price Co., Philadelphia; Rockwell Mfg. Co., Royston Laboratories, Blaw Knox, Pa.; Kenneth Tator Associates, Coraopolis, Pa., Westinghouse Electric Corp. (Unless otherwise specified, all locations are Pittsburgh).

North East '50 Officers Candidates Are Named

Candidates for office of North East Region during the calendar year 1950 have been named as follows by the regional nominating committee:

Chairman—Lewis B. Donovan, Consolidated Edison Co. of N. Y., Inc., 4 Irving Place, N. Y.

Vice-chairman—Hugh L. Hamilton, Keystone Pipe Line Co., 260 S. Broad St., Philadelphia, Pa.

Secretary - Treasurer — E. Rowland English, H. C. Price Co., P. O. Box 6120, Philadelphia 15, Pa.

South Florida Test Service
INSPECTION – TESTING – RESEARCH ENGINEERS
(Established 1931)
Corrosion, weathering and sunlight tests. Four locations in Southern Florida for inland, salt atmospheric, tidewater and total immersion exposure tests.
4201 N. W. 7th St. MIAMI, FLORIDA

SERVING ALL PIPELINES
PIPELINE ASBESTOS FELT
Made by The Ruberoid Co.
COAL TAR ENAMEL COATINGS
Made by Pittsburgh Coke & Chem. Co.
"Steve" Day
S. D. DAY COMPANY
2017 W. Gray Houston 19, Tex.
Phone KE-0407

PROTECTIVE COATINGS
BASED ON COPOLYMER VINYL RESINS
LINETITE
For specific heavy duty applications.
VINYL-CLAD
For general maintenance on exterior or interior surfaces.
VINYL-CLAD SYSTEM
Involves primer to seal off surfaces which cannot be prepared by conventional cleaning methods.
VINYL-CLAD Hi-Resist Black
Chemically inert and high abrasion qualities.
Descriptive literature and samples available on above products.
PLASTIC LINING CORPORATION
PROTECTIVE PLASTIC COATINGS
914 South Wabash Avenue Chicago 5, Illinois
World's Pioneer of Vinyl Industrial Protective Coatings

CORROSION DIRECTORY
Rates for notices under this heading can be obtained from National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas.

STATIONARY COATING & WRAPPING
COMPLETE PIPE RECONDITIONING
Plants – Corpus Christi – Refugio, Texas
Jackson, Miss.
ROSSON-RICHARDS CO.
Box 908–Corpus Christi–Ph 3-5121 & 2-9021
Portable Units Available for Rail-Head Coating Anywhere

CATHODIC PROTECTION
Systems Designed, Installed and Maintained
Consultation service on electrolysis, interference and special corrosion problems.
HUDDLESTON
ENGINEERING CO.
BARTLESVILLE OKLAHOMA

C. I. SIMS
Consulting Corrosion Engineer
Box 761—Dallas, Texas
Telephone Logan 6-3564
Specializing in pipe line and plant corrosion surveys, recommendations and supervision of cathodic protection installations.

CORROSION SURVEYS
Recommendations and supervision of corrosion control methods and protective coating and lining installations.
KENNETH TATOR
ASSOCIATES
Montour St. Ext. Coraopolis, Pa.

CATHODIC PROTECTION SERVICE
Engineering — Installation
Dow Magnesium Anodes, Miscellaneous Supplies and Instruments
1801 Bissonnet, Houston KE 6092
Tulsa, Okla., 314 Thompson Bldg., Ph. 29857

STARR THAYER
Consulting Engineer
Corrosion mitigation on existing structures; protection designed for new structures.
614 S. Standard Bldg. Houston, Texas

Corrosion Magazine
Is a Useful Reference

1950 Corrosion Abstracts Indexing to Be Changed

Effective with the January, 1950 issue of Corrosion magazine the Corrosion Abstracts section will contain abstracts which have been classified according to the NACE Abstract Filing System, which has evolved over the past year from the work of the Abstract Committee of which Miss Marguerite Bebbington, The International Nickel Co., Inc., New York, is chairman.

The filing system index contain eight major subdivisions:

1. General
2. Testing
3. Corrosion Types and Influencing Factors
4. Corrosive Environments
5. Preventive Measures
6. Materials of Construction
7. Equipment
8. Industries

Each of these major divisions is again divided into from five to ten subdivisions. It is possible to designate a major and secondary classification under this system by separating the appropriate index numbers by a point mark.

The principal reason for changing to the new system from the old is the desirability of having one system of indexing abstracts used throughout all NACE publications.

Because of the wide differences in the philosophy of the system of classifying abstracts in Corrosion prior to 1950 and the new method, there does not seem to be a ready means of constructing a simple method of cross-reference between the two systems. In any case this would be of significance only until collected abstracts for 1946-7-8 are published.

The full index will be published in Corrosion for reference.

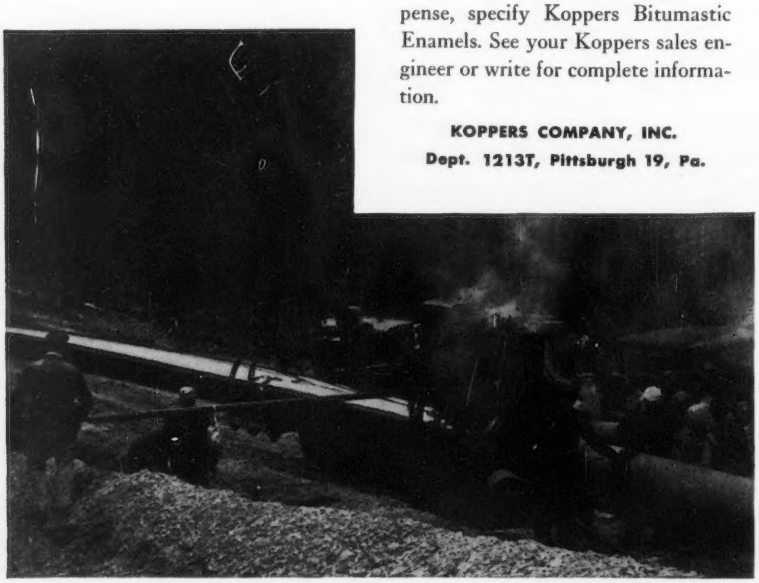
CORROSION
costs more today, too!

PIPE LINES of larger diameter, together with increased pumping capacity, make any break in normal operations . . . including breaks due to corrosion . . . far more costly today. That's why it's more important than ever to give your lines the lasting protection of Koppers Bitumastic ® Enamels.

Processed from a highly-refined coal-tar base, Koppers Bitumastic Enamels form a tough, thick barrier between the pipe and such attacking corrosive forces as moisture and soil chemicals. Bitumastic Enamels have high dielectric strength and do not deteriorate with age.

For lower line maintenance expense, specify Koppers Bitumastic Enamels. See your Koppers sales engineer or write for complete information.

KOPPERS COMPANY, INC.
Dept. 1213T, Pittsburgh 19, Pa.



KOPPERS BITUMASTIC ENAMELS

Policy on Publication Of Papers Is Amended

At a recent meeting the executive commitetee of NACE discussed association policy regarding publication in journals other than Corrosion of papers presented before sectional, regional or national meetings. It was decided that in those instances where preprints are available, permission will be granted to other journals to publish reviews, condensations, or abstracts prior to publication of the complete paper in Corrosion, provided these reviews, condensations or abstracts do not exceed one-third of the total contents of the original paper and provided acknowledgment is given the previous presentation of the paper before an NACE group.

In those cases where preprints are not available the representative of a publication is invited to attend the technical sessions and to make notes to supplement the abstracts supplied by the Central Office to prepare reviews, condensations or abstracts to be used in the manner described.

An opportunity will be provided at national meetings for trade press representatives to check notes against the available original papers. As before, permission to publish the entire paper will be withheld prior either to publication of the paper in CORROSION or decision not to publish the paper in CORROSION.

NACE CALENDAR

METROPOLITAN NEW YORK SECTION—Next meeting scheduled February 8.

PHILADELPHIA SECTION—Engineer's Club, Philadelphia. 6:30 p.m. Informal discussions on three topics scheduled.

CLEVELAND. SECTION—Joint meeting with The Electrochemical Society scheduled for January.

GREATER ST. LOUIS SECTION—Next meeting scheduled December 19.

HOUSTON SECTION—December 13, Group discussion, "Application of Cathodic Protection."

TULSA SECTION—Meets second Monday monthly.

SAN FRANCISCO BAY AREA SECTION — Next scheduled meeting December 6.

Barrett

PROTECTION SERVICE

Covers Every Pipe-coating Need

Materials and Application Procedure for:

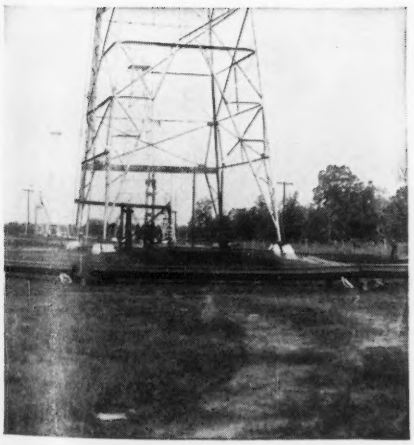
1. Water Industries
2. Natural Gas, Crude Oils and Products Transmission
3. Professional Application in Plants and Yards
4. Distribution Systems
5. Reconditioning Operations
6. Gathering Systems
7. Recycling Operations

Materials and Application Procedure for

GATHERING SYSTEMS

In the natural gas and crude oil industries, gathering systems are taking on constantly increasing importance. With pipe diameters ranging from 2″ to 30″, these systems involve a large capital investment, deserving of the highest degree of care for their protection.

Barrett* Enamels and Barrett Protection Service afford an effective and economical means of extending the useful life of such gathering systems. Pre-coated pipe is easily laid and professional application is available at coating yards, pipe mills or rail heads. Modern equipment also permits economical application over the ditch.



Barrett offers an expert supervision service in connection with application plants and yards. Owners wishing to avail themselves of the advantages of professional application can have the work done with Barrett materials and under Barrett supervision. We will be glad to supply further information upon request.

THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Barrett *

*Reg. U. S. Pat. Off.

Houston Section heard Lyle Sheppard, senior chemist of the Shell Pipe Line Corp., Houston, Texas talk on "The Fundamentals of Cathodic Protection," a condensation of the lecture presented at the Austin corrosion short course September 12-16. The history of cathodic protection from its early development by Sir Humphrey Davy to its present widespread use was related. Fundamental chemical reactions involved in the corrosion process and primary factors contributing to pipe line corrosion were outlined. Cathodic protection, a means of curtailing corrosion by artificially creating an electrical potential difference, was discribed after preliminary discussion. Roles of sacrificial anodes and impressed currents and economic aspects of cathodic protection also were discussed.

A pamphlet, "Anode Resistance" written by Mr. Sheppard was distributed at the meeting. It gave approximate formulas for computing cylindrical anode resistance. Examples of problems were given. The presentation ended with a discussion of a coating resistivity equation Mr. Sheppard developed and its practical use in locating inadequately coated sections of pipe.

Thirty-nine members and guests attended the meeting at Elliot's Cafe.

Sabine-Neches Section's October 29 meeting was a departure from the usual dinner meeting schedule on the Third Thursday monthly. About 20 members and 10 guests convened at Lake Charles, La., and beginning at 3 p.m. Saturday toured the Cities Service Corp. Tutwiler Refinery there, followed by a tour of the newly-constructed lube-oil refinery of the Cit-Con Oil Corporation. A Fellowship Hour was held from 5 to 6 p.m. and an exceptionally fine buffet supper was enjoyed afterward. The after dinner program included a question and answer period concerning both refineries, announcements and entertainment in the form of a color motion picture "Football Highlights of 1948" presented by Humble Oil Co. Masor's Cafe prepared the food. The scheduled December 1 meeting was at the Airport Cafe, Orange, with either a speaker or a paper presentation.

Corpus Christi Section heard Gustave Heineman, chief chemist and technical director for Southern Alkali Corp. discuss "Corrosion in Industries Using Sea Water," following dinner at a meeting at Princess Louise Hotel, Corpus Christi.

WILKINSON
Line Locator

LIGHT
•
HANDY
•
POWERFUL

One-Man One-Hand

A soundly designed, sturdily built, precision locator

This is the locator that has set new high standards for performance. It is indispensable for all pipe line construction jobs and for general maintenance work. It is light but powerful—a simple, one-man tool that does EVERY job. Regardless of depth, no part of your underground pipe system can hide from this electronic sleuth. Its skill in detection is unhampered by conditions that stymie ordinary devices. Especially designed for rough field use and for long distance pipe line jobs.

WILKINSON LINE LOCATOR

(Pat. Pending)

Write for complete literature and prices

WILKINSON PRODUCTS COMPANY

Originators of light weight all-purpose quality locators

P. O. Box 1774, Wilshire-LaBrea Sta., Los Angeles 36, California

'Corrosion Problems' to Be Handled by E. A. Tice

E. Allen Tice, with the corrosion engineering section of the development and research division of The International Nickel Co., Inc., New York has accepted responsibility for handling the Corrosion magazine feature "Corrosion Problems" which was suspended during the summer for lack of material. Mr. Tice is acting vice L. G. Vande Bogart, The Crane Co., Chicago, Ill., who is ill.

Plans are being made now for resumption of the feature, with the January 1950 issue the target.

Some changes in procedure have been announced by Mr. Tice. The principal change in the method of handling the questions will be that all questions destined for publication in Corrosion Problems should be sent first to Norman E. Hamner, Managing Editor, Corrosion, 919 Milam Bldg., Houston 2, Texas, who will send them to Mr. Tice. Replies, as before, will be made both through the magazine and by mail directly where the necessity is indicated, Mr. Tice said. Replies to questions published in the magazine should also be sent to Mr. Hamner for scheduling.

MEETINGS

1950

February

27-Mar. 3—ASTM Committee Week and Spring Meeting. Hotel Wm. Penn, Pittsburgh, Pa.

June

26-30—ASTM 53rd Annual Meeting. Ninth exhibit of testing apparatus and related equipment. Chalfont-Haddon Hall, Atlantic City, N. J.

•

Notices of future meetings of NACE subdivisions are carried monthly under the heading "NACE Calendar" in each issue of Corrosion magazine. Notices for this column should be sent to Central Office.

BOOK REVIEW

METAL FINISHING GUIDEBOOK-DIRECTORY. 18th ANNUAL EDITION. Finishing Publications, Inc., 11 West 42nd St., New York 18, N. Y. $2.00.

The 1949 edition of this reference book contains, among other things, sections on finishing plant engineering, abrasive methods, cleaning, pickling and electropolishing, plating solutions, surface treatment, control and testing, and directories of suppliers of equipment and supplies. The foreword states all technical material has been brought up to date.

STAINLESS STEELS

By Carl A. Zapffe, The American Society for Metals, Cleveland, Ohio. 6 x 9, cloth. 368 pages. Bibliography. Subject Index. $5.00.

An elementary text for consumers of stainless steels, the book should be of interest to many corrosion engineers desiring to apply stainless steels where their resistance to corrosion is important. The book gives a history of stainless steels, defines the fundamentals of passivity relative to the various components of the material, discusses seven minor generalizations, miscellaneous factors, such as sulphur content, stress corrosion cracking, etc., gives specific applications, and gives a table listing 150 chemicals with their effect on four types of stainless in three general classifications.

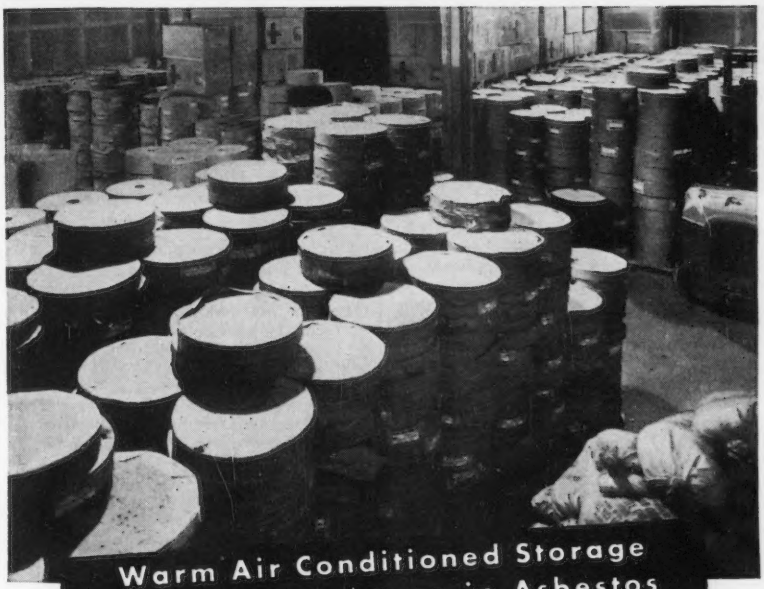
The production, fabrication and finishing of stainless steels in general also is covered.

Dow Tanker Will Carry Caustic Soda, Chemicals

The 12,750-ton tanker "S.S. Marine Chemist, modified to transport chemicals from Dow Chemical Company's Freeport, Texas, plant to Carteret, N. J., was loaded with her first cargo of chemicals October 20 at Freeport. Over 60 engineers and representatives of the press were present for loading ceremonies, inspection of the ship, a tour of Dow's plant and a dinner at Dow's Lake Jackson Club. Dr. A. P. Beutel, general manager of the Dow Texas Division and Arthur Smith, director of public relations, Dow Chemical Co., Midland, Mich., directed the tour.

The ship was converted by Bethlehem Steel Co., Brooklyn, N. Y., for Marine Transport Lines, Inc., owners and Dow Chemical Co., charterers. Modifications included removal of cargo piping, and installation of new piping, new inner bottom throughout cargo tanks, six new transverse cofferdams, renovated pump room and new pumping controls. Cargo separation is by means of cofferdams and independent pipe and pumping systems. A special coating has been installed in caustic soda and propylene glycol tanks for cargo protection and rust prevention.

Cargo space is divided into two dry cargo tanks, one each for propylene glycol, carbon tetrachloride, ethylene dichloride, and ethylene glycol and four for caustic soda.


Warm Air Conditioned Storage
Eliminates Moisture in Asbestos
Felt, Glass and Wrapping Materials
at standard pipeprotection inc.

MOISTURE CONTROL—of wrapping materials before being incorporated into the hot coatings and applied to the pipe—is vital to quality production.

STANDARD'S ELABORATE . . . warming areas . . . 20,000 square feet . . . in addition to ideal material storage . . . provides for elimination of moisture on the pipe before cleaning . . . warm pipe for primer application . . . and especially warm pipe during coating and wrapping operations . . . all this plus electrical inspection at no additional cost.

STORAGE-IN-TRANSIT—Take delivery of your pipe . . . and store it up to 12 months without freight penalty in the largest storage area in the industry . . . through freight rates plus our storage facilities save you money.

Write for Schedules

Existing railroad tariffs permit immediate shipment or stopover up to 12 months without freight penalty. When you ship your pipe through the St. Louis Gateway, you enjoy "through freight rates" instead of the higher combination rates generally used.

standard pipeprotection inc.

3000 South Brentwood Blvd. • St. Louis 17, Missouri

Delivery of November Issues Delayed for Some

Delivery of the November issue of Corrosion magazine to members and subscribers in Texas and at overseas points was delayed fifteen days when, because of a misunderstanding, the number of copies printed was about one-third less than ordered. When the error was discovered, the issue had been mailed to all but Texas and overseas points.

The number of copies of Corrosion mailed each month has shown a steady increase during the year, and there are excellent prospects that an increasing number will be mailed each month in the future.

Two Corrosion Interest Papers Are Scheduled

Among the technical papers scheduled for presentation at the Seventh Annual Pittsburgh Diffraction Conference, Mellon Institute of Industrial Research, Pittsburgh, Pa., November 7-8, were the following:

An X-ray Diffraction Study of Corrosion Products Resulting from Ruptured Surface Films on Steel, by S. S. Sidhu and C. O. Henry, University of Pittsburgh, Pittsburgh, Pa.

Structure of High Temperature Oxide Films on Simple Chromium Steels, by H. J. Yearian, Purdue University, Lafayette, Ind.

Science Internships at NBS Are Being Offered

Outstanding students in science and engineering are offered an opportunity to broaden their undergraduate or graduate training through vacation-time employment and graduate fellowships at the National Bureau of Standards, Washington, D. C. The bureau has an integrated work-study program, beginning at the college sophomore level, for the selection and training of research scientists and engineers. The program permits the student to alternate periods of full-time study with actual work experience in his chosen field, supplemented by on-the-job training and orientation courses at the bureau. The bureau at the same time is given the opportunity to select promising students for permanent appointment to its staff and provide them with opportunities for professional growth and advancement through further in-service training.

The programs of interest to college and university students are: Internship program for undergraduates, the regular training program for college graduates on the staff and the fellowship program for graduates engaged in working for advanced degrees.

Information regarding qualifications for appointment may be obtained from the Personnel Division, National Bureau of Standards, Washington 25, D. C.

Canadian Scientific Journal Sent to NACE

"Revue Trimestrielle Canadienne," of the Association des Diplomes de Polytechnique, Montreal, Canada, No. 138, a publication dealing with engineering, mathematics, sciences, architecture, industry, political and social economics, Finance, history, statistics, hygiene and legislation has been received at Central Office, Houston. The issue contains articles both in French and English. One in English entitled "The Engineer in Industry" being a verbatim report of a forum under the auspices of the association with Prof. Erwin H. Schell, department of business and engineering administration, M.I.T. as guest speaker and Huet Massue, as chairman and Paul-Emile Piche, discussion leader.

NACE NEW MEMBERS and ADDRESS CHANGES

NEW MEMBERS

FOREIGN

COLE, R. J., 7 Wells St., Toronto 4, Ontario, Canada.
HEWITT, HARRY N., 11985 Poincare St., Montreal, Quebec.
KOLFF VAN OOSTERWIJK, A. R., Laboratorium (Koninklijke/Shell), Badhuisweg 3, Amsterdam, Holland.

CALIFORNIA

SCOTT, HAROLD H., 2820 Leslie St., Martinez, California.

ILLINOIS

EASSON, W. H., 2045 Jarvis Ave., Chicago, Illinois.
SKOG, LUDWIG, Jr., Sargent & Lundy, 140 S. Dearborn St., Chicago, Illinois.

LOUISIANA

GURNEY, WILLIAM B., Gulf States Utilities Co., Baton Rouge, La.
MONCRIEF, R. S., 1345 Jennings St., Shreveport, La.

NEW JERSEY

HIGGINS, EDWARD J., 76 Halsted St., East Orange, New Jersey.

OHIO

FLOOD, EARL F., Rd. 2, Hudson, Ohio.
RASK, MORRIS L., 2895 Weymouth Road, Shaker Heights, Ohio.
TEH, CHIN WHAT, International House, 104-15th Ave., Columbus, Ohio.

OKLAHOMA

BOSLEY, SAMUEL E., 1206 S. Xanthus-Str., Tulsa, Oklahoma.
CASE, L. C., 206 Sunset Dr., Tulsa, Okla.
HARVEY, JOHN M., 1823 S. Carson, Tulsa, Oklahoma.
LOVELADY, H. A., 1411 S. Winston, Tulsa, Oklahoma.

PENNSYLVANIA

DIGGINS, EARL READY, 1006 Manor Rd., New Kensington, Pa.
HAMILTON, J. S., 806 Carl Ave., New Kensington, Pa.
RUTHERFORD, JOHN J. B., Patterson Hts., Beaver Falls, Pa.
WHITE, ROBERT L., Box 63, Degolia, Pa.
WILSON, JOHN R., 555 McCully St., McKeesport, Pa.

TEXAS

MANNING, JOHN A., Jr., 3606, Ave. O½, Galveston, Texas.
McGARY, S. U., 854 W. 43rd St., Houston, Texas.
MULVANEY, E. J., Jr., 606 S. Kansas St., Pasadena, Texas.
STEIN, WALTER F. G., Cabot Carbon Co., Box 1101, Pampa, Texas.

UTAH

MALOUF, E. E., 183 Kelsey Ave., Salt Lake City, Utah.

CHANGES OF ADDRESS

(Old Address Follows New Address in Parenthesis)

CALIFORNIA

STORM, ARTHUR F., Tide Water Assoc. Oil Co., Avon, Calif. (Tide Water Assoc. Oil Co., Assoc. Calif.).

ILLINOIS

LAW, JOHN E., 160 Forest, Oak Park, Illinois. (Alloy Steel Products Co., 332 S. Michigan Ave., Chicago, Illinois).

MICHIGAN

HUMBLE, H. A., Cathodic Protection Sales Dept., The Dow Chemical Co., Midland, Michigan. (The Dow Chem. Co., 3615 Olive, St. Louis, Mo.).

NEW JERSEY

BARNES, FRANK H., 42 W. Holly St., Cranford, N. J., P.O. Box 142, Cranford, Cranford, N. J. (The Patterson Sargent Co., 49-20 Vam-Dam St., Long Island City, N. Y.).
RICHARD, CHARLES S., 2608 Manning, N. Plainfield, N. J. (Socony Vacuum Oil Co., Box 229, Holmes, Pa.).

OHIO

BEDFORD, GORDON T., 25 Oakwood Ave., Dayton, Ohio. (c/o Market Development Divn., Armo Steel Corp., Middletown, Ohio).

OKLAHOMA

BALL, JAMES F., Ball Distributing and Engineering Co., 1004 East 34th St., Tulsa, Oklahoma. (Owen-Corning Fiberglas Corp., 222-223-224 Mayo Bldg., Tulsa, Okla.).

PENNSYLVANIA

LEMAY, JACK E., 305 Arden Rd., Pittsburgh, Pa. (National Carbon Co., Inc., 1715 Clark Bldg., Pittsburgh, Pa.).

TEXAS

MEED, J. GORDON, Metal Goods Corp., 1923-A, Ave. Q, Lubbock, Texas. (Metal Goods Corp., 217 College Ave., Lubbock, Texas).

VIRGINIA

BUTLER, EDWARD B., 525 Knollwood Dr., Dora Lee Apts.—Apt. 102, Falls Church, Virginia. (6734 Ridgeland Ave., Chicago, Illinois).

DECEASED

BLACK, ERNEST B., Black & Veatch, Consit. Engrs., 4706 Broadway, Kansas City 2, Mo.

NEW CORPORATE AND ASSOCIATE MEMBER

During the period from the last published report through November 15, the following corporate and associate members have joined the National Association of Corrosion Engineers.

Sargent & Lundy, Chicago, Ill. ..... Ludwig Skog, Jr., Representative

NEW PRODUCTS—Materials—Service—Literature

Fischer & Porter Co. primary and secondary flow instruments and control valves for all industries are described in a new 24-page illustrated Catalog 50 available from the company, 50 County Line Road, Hatboro, Pa.

K-Shield, a light weight pipe and vessel insulation made of Styrofoam, an expanded plastic, is rigid and highly workable and is its own moisture barrier, according to Robinson Industries, Coleman, Mich., manufacturers. It is being used where temperatures range from 175° F. to minus 250° F.

"Chlo-Dur" a chlorinated rubber material recommended for use on concrete, wood or metal above and below water, also has high resistance to alkalis in concrete, the Brooklyn Varnish Mfg. Co., Inc., 50 Jay St., Brooklyn, N. Y., claims.

Polyethylene Coated papers are being used by W. Ralston & Co., Inc., Old Bridge, N. J., for the production of heat-sealing case, bag and barrel liners in flat and creped form where the material's resistance to acids, greases and moisture are useful.

Control To Within three parts in the fifth decimal place in refractive indices ranging from 1.32539 to 1.54409 is claimed by Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill., for its Precision - Dow Robomatic Refractometer. The device is recommended for control of products flowing through pipe lines in chemical plants.

Metalweld, Inc., 26th & Hunting Park Ave., Philadelphia, Pa., is offering two bulletins: What Metallizing Can Do for You, and Koroseal Lining.

"Vinyl Polymers and Surface Coatings," by C. W. Patton, a pamphlet published by the Bakelite Corp., 3615 Olive St., St. Louis 8, Mo., describing in general terms the specific uses of vinyl polymers for surface coatings is available on request. Methods of formulation and specifications are discussed in laymen's terms. The material, taken from an address before the New York paint and Varnish Production Club, was reprinted from the May, 1948 issue of "Official Digest" of the Federation of Paint and Varnish Clubs.

A Portable Plating set designed for use in laboratories, by platers, schools and by hobbyists is soon to be marketed by Guild Laboratory, P.O. Box 3194, Barnum Station, Bridgeport, Conn. The set to be known as the Guild Plate-Kit, can be operated from a 110-v AC power source. The laboratory also will produce plating solutions and concentrates for nickel, silver, cadmium and brass and will offer a consulting service.

Acid-Proof Tantalum bayonet heaters for use in process industries are described in a release by Fansteel Metallurgical Corp., Tantalum Division, North Chicago, Ill.

Klem Chemicals, Inc., Dearborn, Mich., is offering a set of reference file folders of interest to those interested in metals cleaning and other uses of industrial chemicals. The folders facilitate filing under the general headings: Paint Removal, Phosphate Coating, Metal Cleaning and Spray Booth Maintenance.

"Molybdenum-Bearing Stainless Casting Alloy Has Wide Range of Uses," by Norman S. Mott, chief chemist and metallurgist, Cooper Alloy Foundry Co., Hillside, N. J., is available on request. The publication states the alloy has exceptionally good general corrosion resistance as well as increased strength at elevated temperatures. Corrosion resistant properties are defined and recommended uses listed.

Rinshed-Mason's X8350, a corrosion-resistant rail preservative, has been applied as a prime coat and X8352 sprayed on later to rails laid in Great Northern Railroad's Cascade Tunnel. The new continuous rail is prepared by welding rail sections together in a machine under 2500 to 2700 psi. The homogeneous weld is made after five minutes at about 2300° F. The weld is then stress relieved, trimmed and polished. The Rinshed-Mason Company, 5935-71 Milford Ave., Detroit 10, Mich., manufacturers of the rail coating, assert the material retains flexibility under severe temperature variations. The coatings, specifically formulated to protect rails against the corrosive conditions in tunnels, also are believed suitable for protecting them under other conditions, such as in some train sheds, on tracks running close to salt water, at grade crossings where water is trapped against the rails, on lines carrying heavy refrigerator car traffic where brine drippings are continuous, besides other rust-preventive applications. Continuous tests of the material are being made by manufacturers.

Dekoron Armor for electrical conduits, a polyethylene thermoplastic available in any thickness and color is recommended for service in corrosive environments by the manufacturers, Samuel Moore & Co., Mantua, Ohio. Characteristics of the material are defined by the company as follows: Specific gravity .92-.93; heat resistance, continuous 212° F; dielectric strength is good; is not affected by weak or strong acids or alkalis, water absorption is less than .01 percent, is not affected by organic solvents below 50° C. It is applied to the tubing by a patented extrusion process. Damage to the coating incident to handling can be repaired quickly by a Polyken (Bauer & Black) tape wrapping. Standard couplings may be used. The material also may be applied to water and gas pipes, air lines, and other tubular bar forms.

Glass Cylinders in a wide range of diameters from 1¼-inch to 8¾-inch and in lengths up to 18 inches now are being manufactured by Dunbar Glass Corp., Dunbar, West Virginia. A descriptive folder on the cylinders will be sent on request.

Zapon Primers and primer surfacers are described in a new folder available from Industrial Finishes Dept., Atlas Powder Co., Stamford, Conn. Points on corrosion resistance are explained.

Platinum and Palladium are important components of industrial heating tubes produced by Federal Radio & Telephone Co. Baker & Co., Inc., Newark, N. J., makes platinum chemical laboratory ware, catalysts and an immersion heater for highly corrosive environments. The glass and synthetic fiber industry rely on platinum and palladium for high-temperature and highly corrosive service.

Walworth Co., 60 East 42nd St., New York 17, N. Y., is offering a comprehensive line of corrosion-resistant valves in Monel, pure nickel, acid-resisting bronze, Ni-Resist and several types of stainless steel. Available in these materials are 150-pound gate, globe, angle and swing check valves; 150-pound quick opening gate valves and 300-pound gate valves. In screwed ends in sizes from ½ to 3 inches with the exception of 300-pound gate valves, which can be supplied with flanged ends only, and in sizes from 2 to 6 inches; 150-pound gate and swing check valves are available in ½ to 12-inch sizes with flanged ends, while 150-pound quick-opening gates and the globe and angle valves can be supplied with flanged ends in sizes ½ to 6 inches only. Walworth Stainless Steel Gate Valves are all outside screw and yoke design. This company also makes lubricated plug valves in Type 316 stainless steel Monel, nickel and acid-resisting bronze.

National Graphite combustion chambers and impervious graphite burner nozzles are described in a booklet available from National Carbon Co., Inc., 30 East 42nd St., New York 17, N. Y. It is Catalog Section M-9602, "National Graphite Combustion Chambers and Karbate Burner Nozzles."

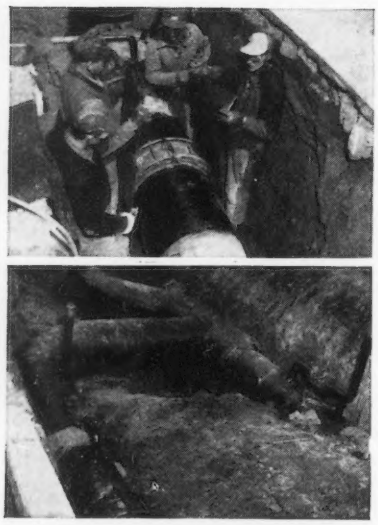
Unichrome SRHS Chromium Plating Solution, said to have several advantages over previously used solutions, including higher cathode efficiencies, which cuts plating time from 1/5 to ½, now is being produced by United Chromium, Inc., 51 East 42nd St., New York 17, N. Y. The concentration of the catalyst acid radical is automatically self-regulated, the company says, therefore the solution is always in good plating balance.

"Corrosion Inhibition in Recirculating Water Systems," a new pamphlet being distributed by Mutual Chemical Co., of America, 270 Madison Ave., New York 16, N. Y., discusses five types of corrosion control: Cathodic polarization, preventing harmful deposits, removal of corrosive constituents, adjusting the pH. The pamphlet also contains late experimental data on the inhibitive action of chromate concentrations. The booklet is "Serial No. 53." "Properties of Technically Important Hexavalent Chromium Compounds," Mutual's Serial No. 56, also available on request, presents new data on a number of chromium compounds and includes an extensive bibliography.

NEW WIDE

TAPECOAT*

Makes Tough Jobs Easy



- JOINT COATING ON LARGE DIAMETER PIPE
- WRAPPING MECHANICAL COUPLINGS
- PROTECTING LARGE PIPE BENDS

With TAPECOAT now available in 18 and 24-inch widths, you have a practical answer for those hard-to-handle jobs in the field. This COAL TAR wrapping in handy tape form provides protection equal to the mill coating on the pipe and with the regular widths from 2 to 6 inches and the new widths of 18 and 24 inches can serve you on the smallest or the largest jobs. Write for details or ask our service engineers to demonstrate actual field applications.

*Reg. U. S. Pat. Off.

The TAPECOAT Company
1523 Lyons Street • Evanston, Illinois
New York Office
469 Fifth Ave., New York 17, N. Y.
Houston Office
Jas. E. Mavor Co., 514 M and M Building
Houston 2, Texas
Denver Office
175 Niagara Street, Denver 7, Colo.

NEW PRODUCTS

Polyken Tape, an oriented polyethylene film with a synthetic adhesive on one side is recommended for application to piping where corrosion-resistance is important. It can be applied without heat, solvents, or greases, according to Bauer & Black, division of The Kendall Co., 222 W. Adams St., Chicago 6, Ill. Performance data and testing samples will be supplied on request. Inquiries should be addressed to Plastic Engineering & Sales Corp., P. O. Box 1037, Fort Worth, Texas.

PERSONALS

W. R. Smith has been named sales manager for the Mat Division of Glass Fibers, Inc., Waterville, Ohio. He lives in Toledo, Ohio.

John G. Wild, for the past 12 years specialist in the field engineering of synthetic resin coatings, has been named assistant sales manager of Prufcoat Laboratories, Inc., Cambridge, Mass., manufacturers of special coatings resistant to chemical corrosion.

Frank E. McNulty has been named manager of the Tulsa office of Pittsburgh Coke & Chemical Co. protective coatings division and **B. H. Means** has been named service manager of protective coatings for the United States by the firm, according to Russell H. Coe, national sales manager.

Sidney Val Smith, a Texas A. & M. graduate, has joined the sales engineering staff of Plastic Coating Corp., Houston.

Wayne Karber, recent graduate of Michigan State College, has joined Wm. G. Boales & Assoc., Detroit, Mich., as a sales engineer in charge of cast stainless steels.

Arthur Smith, Jr., has been named director of public relations for The Dow Chemical Co., Midland, Mich. All public relations activities will be integrated under Mr. Smith. **L. H. Woodman,** former director of editorial service, will supervise institutional publications and releases, and **Eugene E. Perrin** will supervise product promotion.

Risque L. Benedict, a MIT graduate with a BS in chemistry specializing in metallurgy and corrosion in his senior year and lately employed by A. V. Smith Co., is interested in obtaining work making electrolysis surveys or doing research work in corrosion.

Dr. F. N. Speller announces that the revision of his book titled "Corrosion—Causes and Prevention" is nearly complete. Dr. Speller, who has devoted a long career to the study of corrosion, is still active in the corrosion consulting field, maintaining offices at Tyler, Texas, and Pittsburgh, Pa.

IF IT'S IRON OR STEEL

REMEMBER to have it HOT DIP GALVANIZED

(DIPPED IN MOLTEN ZINC)

A *heavy* coating of zinc applied to iron or steel by the Hot-Dip Galvanizing process provides the utmost protection against rust. Molten zinc forms a perfect bond with the metal, providing an effective seal against corrosive action of the elements. For an economical top-grade job of genuine Hot-Dip Galvanizing, send your materials to a member of the American Hot Dip Galvanizers Association. List of members available at Association's headquarters in the First National Bank Bldg., Pittsburgh 22, Pa.

NOW! Immediate Delivery on

CATHODIC PROTECTION

A SYMPOSIUM

A Book Consisting of 23 Papers Presented at the Joint Symposium on Cathodic Protection Sponsored by The Electrochemical Society and The National Association of Corrosion Engineers at Pittsburgh, Pa., December 8-10, 1947.

Cloth Bound, 8½ x 11, 203 Pages

A valuable book for reference and information on many interesting, instructive and practically useful aspects of cathodic protection. Anyone concerned about the deterioration of plant from electrolytic action will find this a book well worth having. Diagrams, tables, references, illustrations.

To Members of Electrochemical Society and National Association of Corrosion Engineers, Per Copy $6.00

To All Others, Per Copy $8.00

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

919 MILAM BUILDING, HOUSTON 2, TEXAS

Use the Convenient Order Blank Below to Order Your Copy:

23 Papers
By Authorities
on
CATHODIC
PROTECTION

To: NATIONAL ASSOCIATION OF CORROSION ENGINEERS
919 Milam Building
Houston 2, Texas

Please ship me by return mail _____ copies of CATHODIC PROTECTION—A SYMPOSIUM.

I am (not) a member of (Check One) NACE ( ) ELECTROCHEMICAL SOCIETY ( ). Check One: I wish to be billed for this book at $_____.

I am enclosing check for $_____.

Name _____

Street _____

City _____ Zone _____ State _____

ESSENTIAL INFORMATION FOR AUTHORS OF TECHNICAL PAPERS TO BE PRESENTED at NACE 1950 CONFERENCE IN ST. LOUIS April 4-7

Authors are advised that a NACE prerequisite is authority to publish first in its official journal CORROSION, manuscripts presented at national, regional or sectional NACE meetings. Extensive abstracts are released to publications other than CORROSION on request. Requests for copies of papers by other publications should be referred to the Central NACE office in Houston.

By November or as Soon Thereafter as Possible:

Authors are requested to supply quadruplicate copies of a summary of the paper of not less than 350 or more than 500 words, distributed as follows:

(a) Two copies to symposia chairman. (Symposia Chairman sends one copy to Technical Progress Chairman.)

(b) Two copies to Central NACE Office.

(c) These summaries are: 1) used to prepare publicity for the conference. 2) distributed to interested publications. 3) in abridged form appear in the official program.

Before January 1:

The submission of three complete copies before January 1, one of which should be an original with original figures or figures suitable for reproduction, is requested. The distribution of these copies is as follows:

(a) One copy, with figures, to the chairman of the symposium into which the paper falls.

(b) Two complete copies to Central NACE Office, 919 Milam Building, Houston 2, Texas. (One of these copies should be original with original figures.)

GENERAL INFORMATION

Copies of all correspondence about papers should be sent to Technical Program Chairman and Central NACE Office.

Arrangements contrary to these must be arranged by application to symposia chairmen.

Authors interested in reprints should address inquiries to Central NACE Office directly.

Authors are requested to submit a suitable 5 x 7 inch or larger glossy print photograph to be used to make a cut to appear with the paper if published. A short biography of 50-75 words also is requested. Request for submission of a photograph and biography should not be construed as a commitment to publish a paper.

NACE will endeavor to collect questions asked during presentation of papers at conferences, or remarks about papers and submit them to authors of papers for replies if any are needed.

See November Corrosion, Pages vii-ix for Data on Making Slides

Corrosion Abstracts

ATMOSPHERIC

Corrosion in the Air, J. W. Crampton, C.I.L. *Oval,* (Canada) **18,** No. 1, 18-19 (1949) Feb.

The first defense against corrosion in aircraft lies in the fact that most of the metal used to build them is aluminum. However, due to other elements added to produce a high-strength alloy some means of protection against corrosion must be employed. At the Canadian Limited plant much of this protection is provided by the use of Alclad sheet from which the skin and other parts are constructed. Other metals usually are plated, for example, steel rams of the oleo-legs in the undercarriage, are plated with cadmium or chrome. All aluminum parts (except exterior skin) when assembled into an air-frame are anodized in either a chromic or sulphuric acid bath. Each of the rivets which hold the wings and fuselage together is anodized by the manufacturer. As a further precaution where dissimilar metals are in contact, zinc chromate paste is used as insulating material. The fabric surfaces of elevators, rudders and ailerons, especially if the aircraft is to be operated in tropical climates, are treated with a fungicide, usually zinc dimethyldithiocarbamate or zinc naphthanate.—ALL.

Stop that Corrosion!

ON LAND! Pipelines, Tank Bottoms, Gathering Systems, Gas & Water Distribution Systems

ON SEA! Offshore Drilling Platforms, Offshore Pipe Lines, Wharves, Piers, Ships, Barges, Drydocks, Wellheads

IN THE AIR! Water Tanks, Condenser Heads

CPS Offers — A complete sales, engineering and installation service.

1. The MATERIALS

CPS handles only first line materials. **Dowell** Magnesium Anodes—highly developed through years of research and backed up by exact performance data. **General Electric** Rectifiers—the only real advance in rectifier design in years. Stacks only oil immersed in cans provide for low initial cost and easy maintenance. **Maloney** Insulating Materials—**M-Scope** Pipe and Cable Finders—**Cadwell** Welding Supplies—**Rubicon** Potentiometers—Soil Resistivity Apparatus—**Holloway** Shunts—Miscellaneous Instruments.

2. The "KNOW HOW"

Over eighty years of combined experience of seven corrosion engineers at your service to help you apply CPS materials and obtain desired results economically —serving you in an advisory capacity as sales engineers or as design engineers.

3. The FACILITIES

Powered earth augers mounted on rugged mobile equipment, wire and cable plows, shop prefabrication facilities at your service make for fast and economical installation of first line materials in accordance with best design and engineering practice.

CATHODIC PROTECTION SERVICE has completed or in progress design and installation of cathodic protection on fifteen offshore drilling rigs using a combination of the *Electrocoating Process and cathodic protection.**

** To which CPS holds exclusive license under U.S. patent numbers 2,200,469 and 2,417,064.*

CATHODIC PROTECTION SERVICE

Everything in the Cathodic Protection Field from an Insulating Washer to a Turnkey Contract Installation

HOUSTON, TEXAS
1801 Bissonnet
Phones JA-5171 - KE-6983

TULSA, OKLAHOMA
310 Thompson Bldg.
Phone 2-9857

Corrosion of Water Heaters by Flue Gases. I.—Effect of Temperature on the Corrosion of Tin-Lead Coatings. R. Kerr and S. M. Withers. *J. Inst. Fuel,* **22,** No. 125, 204-208 (1949) April. In progress.

Describes an apparatus in which the corrosion (mainly due to SO_3) of 80-Lead-20-tin coatings on copper by flue gases can be determined at steady temperatures of 38-125° C. The corrosion was found to be a maximum at both 57° C and 92° C; these temperatures correspond approximately to the "acid-free" and "acid" dew-points of the gases (terms which are explained in an appendix to the paper).—BNF.

The Oxidation Rate of Nickel. Oswald Kubaschewski and Ortrud v. Goldbeck *Z. Metallkunde,* **39,** No. 5, 158-160 (1948).

Values for the rate of increase in weight per unit surface area at various temp. have been determined for carbonyl nickel containing carbon 0.04, iron 0.012, oxygen 0.09%, and sulphur nil, and for pure nickel containing silicon 0.07, copper 0.07, iron 0.27, cobalt 0.20, chromium 0.01, and aluminum 0.01%. The results are compared with those of other workers. Absorption of oxygen is represented by the equation $k = Ae^{-Q/RT}$, where A and Q are constants and k is the increase in weight per unit surface area; for normal pure nickel the average value is $k = 0.38\ e^{-45,500/RT}$, while for super-pure degassed nickel $k = 3.2 \times 10^{-4}.\ e^{-36,000/RT}$ (at 50 hr.). Impurities present in the metal have the effect of increasing the rate of oxidation. The results also are probably dependent on the time and temperature range of the determinations.—MA.

Aperçu Succinct des Expérienies Atmosphériques de Longue Durée de la Commission Suédoise de Corrosion. (A Brief Summary of the Long-Term Atmospheric Exposure Tests of the Swedish Corrosion Commission). E. Palmaer. *Metaux et Corrosion* (France). **23,** No. 280, 285-8 (1948) Dec. (in French).

A report on the extensive corrosion tests being carried out at eight sites in Sweden. The test samples consist of various steels, painted, zinc coated and unprotected. Though some of the tests were started in 1938, no conclusive results are yet available on the relative merits of the various protective systems,

because of the mild character of the Swedish atmosphere. Zinc chromate and zinc oxide are among the primer pigments being tested, and hot dip galvanized sheets are being compared with zinc sprayed specimens.—ZDA.

Corrosion of Zinc Roofs. M. Pourbaix. *Metaux et Corrosion*, **23**, No. 278, 215-225 (1948) Oct. (In French.)

Experimental work on the corrosion of zinc (two purities) in stagnant and moving waters is described. Results applied to zinc roofs where premature failures were usually due to incorrect material under zinc. Recommendations based on theory and further experiments. —BNF.

CATHODIC PROTECTION

Chemical Aspects of Corrosion. I. A. Denison. *Amer. Gas Assoc. Monthly*, **30**, No. 9, 30 (1948).

A lecture on the study of the effect of chemical constituents both in the metal and in its environment on corrosion. Cathodic protection by zinc and magnesium is mentioned.—MA.

Cathodic Protection of Underground Systems. Joe Frink. *Amer. Gas J.*, **167**, No. 3, 27-29 (1947).

F. discusses the electrochemical series, various types of corrosion, and the application of cathodic protection by means of anodes or rectifiers.—MA.

Cathodic Protection (Use of Magnesium Anodes). *Light Metals*, **11**, No. 131, 674-681 (1948) Dec.; **12**, Nos. 132, 133, 43-50, 84-93 (1949) Jan., Feb.

Review based mainly on literature, concerning causes and inhibition of chemical attack on steelwork principally by soils or in soil environments. In the first part development of systems in present use is discussed, in particular, use of magnesium anode to safeguard pipe lines. Second part concludes discussion of anodes and considers problems of backfills. Third part deals with installation details and results obtained in various cases.—BNF.

Zinc Anode Protection Installed During Pipe Line Construction. O. C. Roddey. *Oil and Gas J.*, **46**, No. 51, 87-8 (1948) Apr. 22.

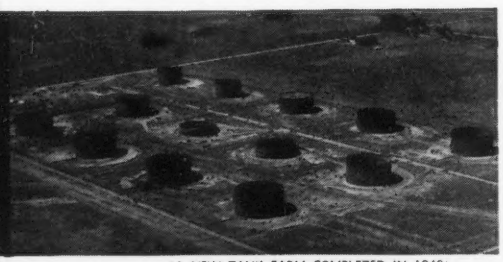
A description of zinc anodes used to counteract the corrosion of a buried pipe line. The anodes were cast and were ⅜ in. diameter, 48 in. long, weighed 17.8 lb. and had a ¼ in. soft iron core. They were set 15 ft. away from the pipe and connections were welded on. The maximum anode spacing for the adequate protection of a 12 in. pipe was considered to be 300 ft. The pipes were also coated with a protective enamel.—ZDA.

Mitigation of Corrosion on City Gas Distribution Systems. A. D. Simpson. *Corrosion*. **5** No. 2, 59-69 (1949) Feb.

A full account of the development of the use of galvanic anodes for protecting underground gas pipes in Texas. Experiments were made on a length of old and poorly protected pipe in Houston, where there were many stray cur-

NATASCO

A MILLION DOLLAR INVESTMENT PROTECTED WITH NATASCO



(A NEW TANK FARM COMPLETED IN 1948)

The owner of this tank farm knows the value of Natasco products and service. The proper Natasco coatings were selected and then applied to the interior of these tanks by experienced Natasco workmen to provide the maximum protection from corrosion. Whether your tanks are just being erected or have been in service for years, Natasco protection will make them last many years longer at a reasonable cost and is *backed by the Natasco Guarantee.*

Why Natasco Products give longer life to tanks

1. They are insoluble in petroleum and petroleum vapors.
2. They are chemically inert in dilute solution of sulphuric and hydrochloric acids.
3. They are chemically inert to hydrogen sulphide.
4. They are impervious to gases.
5. They have high dielectric strength.
6. They are elastic, withstanding the stresses of expansion, contraction, and bending of metal without rupture.
7. They have adequate film thickness.
8. They adhere to metal, wood or cement.

Let Natasco's years of experience be your guide in proper tank protection. Telephone, call or write for complete information.

"NATASCO PROTECTS NEW TANKS NEW... MAKES OLD ONES DO..."

PROTECTS TANKS AGAINST CORROSION — THE Natasco COMPANY — P. O. BOX 1318 TULSA, OKLAHOMA

Lease Tank Service—West Texas Area: Williams Construction Company, Odessa, Texas

California Representative: Coast Contractors, Ltd., 4636 E. Slauson, Maywood, Cal.

PAINTING MAINTENANCE FOR INDUSTRY

Specializing in the Utility and Industrial Fields

SERVING THE NORTHEAST REGION

Devoted to the proper preparation of surfaces and the application of anti-corrosive material.

Inquiries Invited

WILLIAM G. PITTMAN

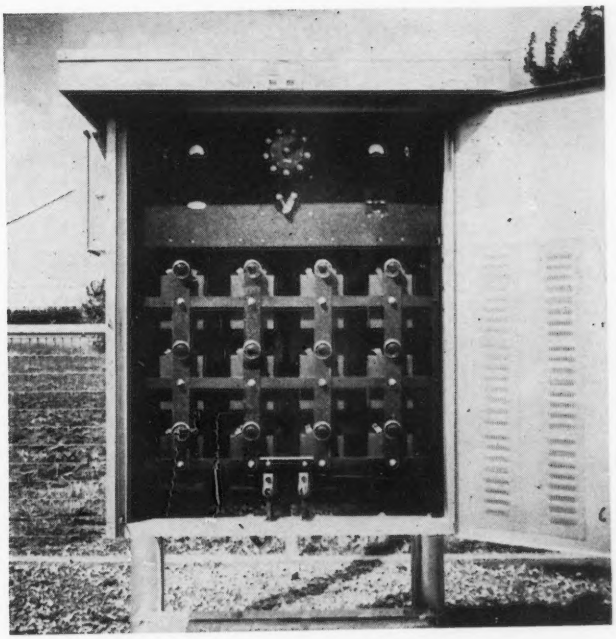
210 MAIN STREET, HACKENSACK, N. J.

HAckensack 3-5185

N.A.C.E. Member

GOOD-ALL

SELENIUM RECTIFIERS



"The Heart of Efficient Corrosion Control"

Accepted and endorsed because of the many outstanding exclusive features, insuring long-life and higher efficiency.

Good-all Selenium Rectifiers are engineered to meet exacting demands. Available in either oil immersed or air cooled models.

Manufactured by **GOOD-ALL ELECTRIC MFG. CO., Ogallala, Nebraska**

National Distributors

CATHODIC SERVICING CO.

1024 NORTH OLIE STREET PHONE 7-5890

OKLAHOMA CITY, OKLA.

rents and contacts with other underground pipes. The gas pipe was carefully insulated from all other pipes and structures, and zinc anodes fitted. Results were so satisfactory that in 1944 galvanic protection was extended to all the gas pipes in the business section of the town, and corrosion leaks fell from 19 to one a year. Zinc anodes are preferred to magnesium for protecting new or well coated pipe in soils of resistivity below 2500 ohms per cm. cube, where they can supply a small current for many years. Magnesium anodes are used where a greater current density is needed, but have a shorter life. Details of anode construction, installation and of the cost of the work are given.—ZDA.

AT LAST!

Development in the past fifteen years of improved and fully proven coatings, NOW permit a long desired ASSURANCE for you in

GUARANTEED APPLICATIONS

These services are promptly available throughout Texas and Louisiana:

A. COMPLETE PLANT SURVEY of corrosion problems with advisory service at no obligation.

B. A GUARANTEED maintenance program on tanks and steel structures wherein a PRE-DETERMINED COST extending over 9 to 12 years, averaging 3½ cents per sq. ft. per year can be properly budgeted.

C. A THREE YEAR GUARANTEE on *Sour Crude, Acid Sludge* and *Gasoline* storage tank linings.

We invite your inquiry. It will be given prompt attention.

CORROSION Engineering Co.

1814 Richmond
Houston 6, Texas

"We Stay Ahead of the Rust Instead of Behind It"

Cathodic Protection Applied to Gas and Electric Utility Operations. W. J. Schreiner. *Corrosion*, **5**, No. 1, 17-24 (1949) Jan.

Describes actual cases of cathodic protection of power cables and gas mains by installation of rectifiers or magnesium and aluminum anodes. The use of the Columbia Rod, which measures the corrosive nature of soils by the galvanic current set up between copper and steel electrodes, is mentioned.—BNF.

Principles of Cathodic Protection Design. L. P. Sudrabin and Frank P. Macdonald, Electro Rust-roofing Corp., Belleville, N. J. *J. Am. Water Works Assoc.* **40**, 489-494 (1948) May.

Intelligent application of cathodic protection helps reduce costs in the waterworks industry. Consideration must be given to economy as well as to all of the design determining factors, such as water characteristics, the locality, and the type and size of the structure to be protected. Water characteristics are the most important to be considered. Temperature is also serious because of the greater corrosiveness of water at higher temperatures.

Cathodic protection for an installation, such as an elevated storage tank or clarifier, will include a rectifier if electrolytic anodes are used, an anode system, various cables, and fittings. The type and size of rectifier depends on the current density needed to protect the submerged metal under the physical conditions at which the rectifier is to be installed. This density may vary from 0.2—20 ma per sq. ft. The type, size, and spacing of anodes depend first on the necessity of distributing the protective current to all parts of the structure, and second upon the size and shape of the structure, water characteristics, and temperature.

On large tanks with relatively large bottom areas, anodes may be placed in a horizontal position. Where only vertical anodes are used they must be long enough to distribute an adequate current density to the floor. In elevated tanks having large-diameter steel riser pipes, a separate full-length anode is recommended for the riser pipe with current supplied to the riser anode from a separate circuit in the rectifier.

Electrolytic anodes may be either of the expendable or non-sacrificial types, each energized by an external direct current. Expendable anode materials include aluminum, iron, carbon steel, and chrome steel; nonsacrificial material are carbon graphite and platinum. Magnesium, aluminum, and zinc usually are used for galvanic anodes, with protective coatings permitting more extensive application of this type of anode.—PDA.

when you consider CATHODIC PROTECTION look to E.R.P.'s facilities

... top-notch research engineers and development facilities.

... a skilled engineering and design staff.

... trained field engineers for special surveys.

... first line equipment—Dow, Alcoa, Federal, Westinghouse, G.E. and others.

... specialized service and installation crews conveniently located to give prompt service.

At E.R.P., your corrosion problems get the individual attention necessary for successful solution. There's no obligation. Write today.

ELECTRO RUST-PROOFING CORP., (N. J.)
BELLEVILLE 9, NEW JERSEY
REPRESENTED IN PRINCIPAL CITIES

E-9

CONSTRUCTION MATERIAL

Corrosion. M. G. Fontana. *Ind. & Eng. Chem.*, **41**, 81A-82A (1949) Jan.

New polymerized acrylonitrile fiber called Orlon exhibits good to excellent resistance to mineral acids, fair resistance to weak alkalies, and good resistance to common solvents, oils, neutral salts and most acid salts. Resistance to microorganisms, marine bacteria, insects, mildew, soils, and sunlight is reported as excellent. Mechanical and physical properties of Orlon are shown in table. Manufactured by Du Pont Co.—INCO.

Corrosion-Resistant Cements and Plating-Room Practice. V. A. Curll. *Plating*, **35**, No. 10, 1008-1011 (1948).

C. stresses the importance of using resistant cements in the construction of floors, drains, and brickwork tanks. He mentions the limitations of Portland cements in these applications and reviews the properties and uses of three major groups of resistant cements, namely silicate type, synthetic-resin type, and sulphur type.—MA.

Packless Valve. *Chem. Eng. News*, **27**, No. 6, 374 (1949) Feb. 7.

A standard series of corrosion-resistant metal bellows of all-welded construction which seal valve stems against any and all corrosive agents was developed. These valves give extended protection from leakage traceable to corroded seats, stems and packing. Manufactured by Cook Elec. Co.—INCO.

Volumetric Measurement. *Chem. Eng. News*, **27**, No. 7, 460 (1949) Feb. 14.

Stainless steel chemical meters for the volumetric measurement of corrosive liquids such as caustic soda, most acids, fruit juices, liquid soap, molten sulphur and vinegar. Outer castings are of 316 stainless, cast iron, cast bronze, or high-pressure cast carbon steel. Manufactured by Buffalo Meter Co.—INCO.

Alpeth Cable Sheath. R. P. Ashbaugh. *Bell Labs. Rec.*, **26**, No. 11, 441-444 (1948) Nov.

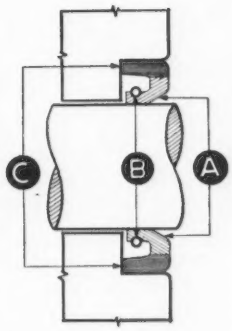
Owing to the growing shortage of lead in the United States, development of a substitute for its use in cable-sheathing

TWIST IT . . . squeeze it . . . drop it . . . hammer it—the new one-piece concentric molded J-M Clipper Seal has plenty of give and take to help it stand up in service.

This flexibility has its advantages. The Clipper Seal's hard, tough outer heel, for example, is resilient enough to conform even to a slightly out of round cavity. Yet the soft, pliable *inner* lip always maintains a light, but positive sealing pressure on the shaft, with minimum wear on the seal.

The simple design of Clipper Seals also assures quick, easy installation, and permits removal without damage so that the seal may be used again. And because Clipper Seals are entirely non-metallic, they eliminate any possibility of electrolysis or corrosion.

Clipper Seals are made in both split and endless types . . . are available, for shafts in sizes from ¼" I.D. up to 68" O.D. They are for sealing against oil, grease, water, coolants at operating temperatures up to 450°F. Write for folder PK-31A to Johns-Manville, Box 290, New York 16, N. Y.



Here's how *Clipper Seal* works:

The lip (A) is held in light but firm contact with the shaft by means of a specially designed garter spring (B). Pressure on shaft is carefully pre-determined to minimize wear, yet effectively seal against leakage. The heel (C) provides a press fit in the cavity, assuring a tight lubricant-retaining seal at this point also. This design is readily varied to meet special conditions.

Johns-Manville **PACKINGS & GASKETS**

has been proceeding for some time. A triple coating of brass-plastic-brass was thought desirable but in response to immediate widespread demand the present coating was produced commercially in Oct., 1947. It consists of corrugated aluminum strip folded round the cable core and cemented together by a water-resistant cement (composition not specified), with an extruded outer covering of polyethylene, and is stated to be less susceptible to fatigue than lead.—BNF.

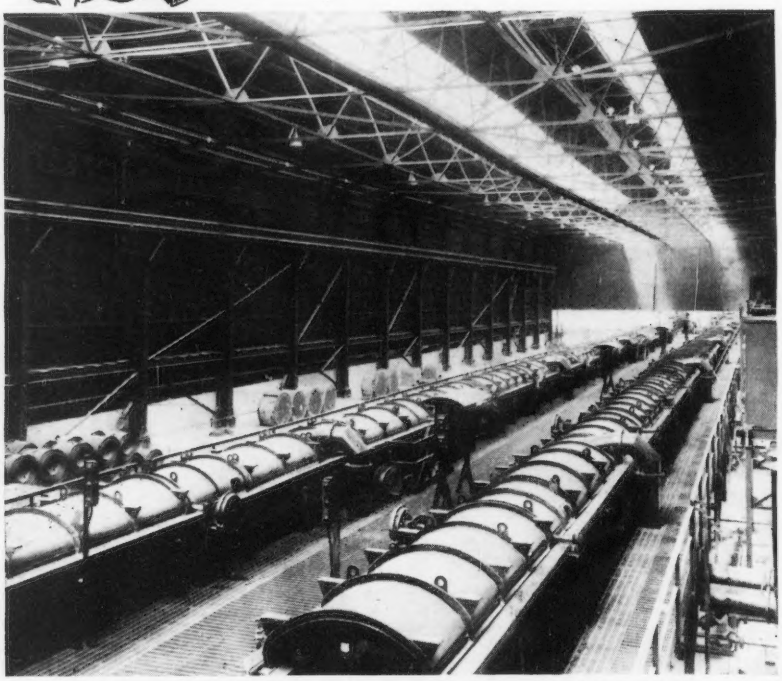
Replacement Metals (Aluminum) for Copper in the Construction of Trolley-Wires for Tramways and Trolley-Buses. LOUIS ALBERT. *Rev. Aluminium*, **140**, 3-12 (1948).

An account is given of recent French experience in the use of materials other than copper for overhead contact lines. The materials used are the aluminum alloys Alutroll, Almélec, or Almétrac, or aluminum-steel composites with the steel supplying the wearing surfaces. It is concluded that the replacement of copper by these substitutes is technically possible and economically desirable.—MA.

How to Cut Corrosion Costs. M. C. MILLER, Esbasco Services, paper before Am. Gas Assoc. Conv., Atlantic City, 1948 Tech Session. *Am. Gas Assoc. Monthly*, **31**, No. 1, 36-37 (1949) Jan.

Economy of correctly installed and used cathodic protection to stop corrosion of underground metallic structures, such as pipelines and gas mains, is discussed. Examples of successful installations are given.—INCO.

For help with your
CORROSION-PROOFING PROBLEMS
. . . look to ATLAS!



Typical Atlas installation for the continuous pickling of steel. Ten tanks 60'x4'x4' and four tanks 25'x4'x4'. Lined with Atlas acid-proof brick joined with Tegul-VITROBOND (R). (The original plasticized sulfur cement.)

Atlas Research and the Atlas record in acid-proof installations have won Atlas leadership as an authority on corrosion-proof construction • Atlas experience and Atlas service, including unbiased recommendation on design and materials, are yours without obligation.

THE ATLAS MINERAL PRODUCTS COMPANY

MERTZTOWN, PENNA. HOUSTON, TEXAS

SURFACE PREPARATION

Brush Anodic Films on to Local Areas (Aluminum). E. SIMON AND F. W. THOMAS. *Machinist*, **92**, No. 28, 911-913 (1948) Nov. 6.

Describes apparatus for forming local anodic films on a Dural-type alloy with a cathode "brush" soaked in chromic acid, and gives some preliminary test results. Suggests that such films may be better than tank-produced films. Discusses application to magnesium.—BNF.

Methods of Protecting the Surfaces of Magnesium Alloys. (In German.) G. SIEBEL. *Metalloberflache*, **1**, 213-220 (1947) Sept.

Describes the various chemical and electrochemical processes and the properties of the different protective films. Tables, graphs, diagrams, and photographs illustrate the report.—BLR.

Die-Castings Must Be Clean, I-A Compendium of Cleaning Cycles Proved in Present-Day Production Practice. ARTHUR P. SCHULZE. *Prod. Fin.*, **12**, No. 10, 26-28 (1948).

Discusses the need for a clean surface before plating and the types of dirt, etc., that have to be removed. Organic solvent washing, vapor degreasing, and emulsion cleaning are briefly considered.—MA.

Shot-Blasting: A Valuable Process for Improving the Surface of Metals. F. SCHRODER. *Metalloberflache*, **1**, No. 4, 87 (1947).

The process of shot-blasting for the pre-treatment of metal surfaces before lacquering, galvanizing, etc., is described. One of its many advantages is that the articles receive a certain amount of cold work, with consequent improvement in their mechanical properties.—MA.

Chromizing Steel Surfaces — Applications. EDWARD ROSEN AND GEORGE BLACK. *Met. Fin.*, **46**, 70-71 (1948) Dec.

Illustrations indicate the variety of applications used successfully by the German war machine. Also includes photographs of various parts chromized in England.—BLR.

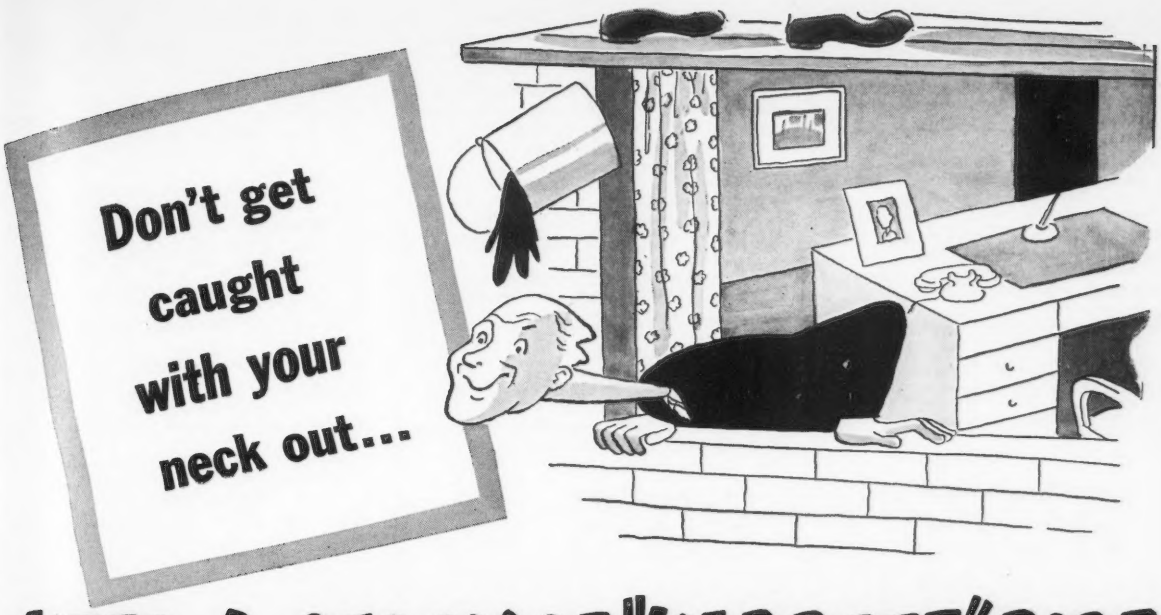
Shot Blasting Replaces Pickling on Some Steel Cleaning Applications. KENNETH ROSE. *Mat. & Meth.*, **28**, 72-75 (1948) Nov.

Describes methods, equipment, and applications.—BLR.

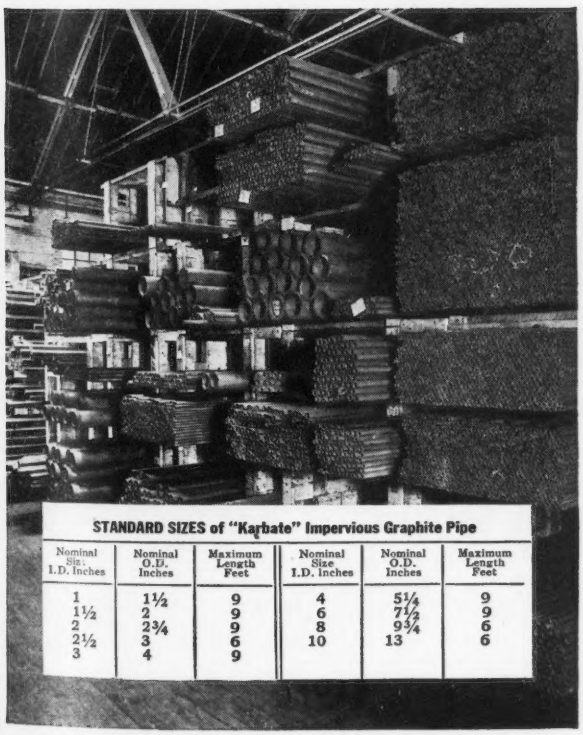
Metallgesellschaft. (Bonderising; zinc and zinc Alloys; Dressing of Ores; Production of Alumina Etc.) Office of Technical Services, PB-70040, Microfilm Reel No. H44; Board of Trade, Ger. Div. (Docs. Unit), FDX 116, 8p.

Reports on miscellaneous subjects of interest to the firm, including corrosion and its prevention, the preparation of and phase-rule work on alumina, analytical methods for the determination of magnesium and fluorine and other subjects of less interest to the paint industry.—RPI.

Korrosionsschutz Kupferhaltiger Aluminiumlegierungen Durch Ausbildung Oxydischer Schutzschichten in Soda-chromatbädern (Corrosion Protection of Copper-Containing Aluminum Alloys Through Formation of Oxidized Coatings in Soda-Chromate Baths). HELLING AND NEUNZIG, Vereingte Aluminium-Werke



KEEP A STOCK OF "KARBATE" PIPE TO HANDLE ANY EMERGENCY!



STANDARD SIZES of "Karbate" Impervious Graphite Pipe

Nominal Size I.D. Inches	Nominal O.D. Inches	Maximum Length Feet	Nominal Size I.D. Inches	Nominal O.D. Inches	Maximum Length Feet
1	1½	9	4	5¼	9
1½	2	9	6	7½	9
2	2¾	9	8	9¾	6
2½	3	6	10	13	6
3	4	9			

KEEP a full stock of corrosion-resistant "Karbate" Impervious Graphite Pipe in an adequate range of sizes and you will never be caught short by an emergency replacement job . . . or have to waste time ordering whenever there is a routine repair to be made. "Karbate" pipe, valves, fittings, towers, pumps, tanks and other equipment offer you many advantages:

- **Both acid-resistant and alkali-resistant**
- **Light in weight, easy to machine and assemble**
- **Immune to thermal shock**
- **No metallic contamination of product**

Write for new Installation Manual, Catalog Section M-8801A, Address Dept. C

The term "Karbate" is a registered trade-mark of

NATIONAL CARBON COMPANY, INC.

Unit of Union Carbide UCC *and Carbon Corporation*

30 East 42nd Street, New York 17, N. Y.

Division Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

Foreign Department: New York, U. S. A.

These products sold in Canada by
Canadian National Carbon Co., Ltd., Toronto 4, Canada

A.G., Grevenbroich, Ger. Office of Technical Services, PB-70015, Frames 966-984 (1938) Jan.

A colorless coating produced on several copper-containing aluminum alloys by a 10-minute immersion in the MBV bath at 95-100° C containing waterglass provided better protection than several other treatments when subjected to corrosion tests. MBV coatings which were subsequently impregnated with a waterglass solution were also essentially more resistant than soda-chromate coatings which offer very little protection in themselves. When 0.3% sodium hydroxide was added to the standard MBV bath there was no improvement in corrosion resistance except in cast alloys having high copper and zinc contents. Coatings produced in a bath containing a larger amount of chromate than usual were equivalent or inferior to the standard MBV coatings. On tempered Igedur 32 and on Lautal, however, they were slightly better.

The surface pretreatment affects the formation of the protective films. Igedur sheets which were oxidized without previous pickling rapidly corroded in most corrosive media even when protected by the very resistant waterglass coatings. Unpickled sheets have an oxide film which is formed during tempering and this prevents the formation of a uniform chromate coating.

On plated sheets corrosion could be decreased, but not prevented, by MBX coatings. In sodium chloride solution metal surfaces were pitted regardless of pretreatment or of the composition of the treating bath.

The densest coating was formed on RR alloys and was entirely protective when the metals were boiled for 15 minutes in a waterglass solution after the normal MBV treatment.

The eight alloys tested included tempered Igedur 32, Albondur, Lautal, Tordal, and RR56, sandcastings of RR 53, and two cast alloys containing 8% copper and 6% copper plus 5% zinc. Sheets and cast samples were exposed to river water, water vapor in a cooling tower, salt spray, and 2% sodium chloride solution with and without hydrogen peroxide. Corrosion behavior was evaluated visually, from weight-loss measurements, and from changes in mechanical properties. Illustrations, tables.—DPA.

ACIPCO PIPE
Resists CORROSION

Mono-Cast Centrifugal Cast Iron Pipe
High resistance to Soil Corrosion

Used extensively for:
- WATER LINES
- GAS LINES
- SEWER LINES
- OIL LINES
- FOAMITE LINES, ETC.

Mono-Cast Alloy Iron
- CONDENSER COILS
- SPECIAL SERVICE

Centrifugally Cast Steel Tubes
- PLAIN CARBON
- HIGH ALLOY, including
- 18/8 & 25/20 CHROME-NICKEL

American
CAST IRON PIPE
Company
BIRMINGHAM 2, ALABAMA

TESTING

Corrosion Testing Device. G. MARSH. *Chem. Ind.*, **52,** No. 6, 968 (1948) June.

Pulse polarizer yields quantitative information on extent to which metals polarize in given media for corrosion testing and may be used as a rapid means for obtaining corrosion rate of metal. It consists of a high-voltage pulse circuit, sensitive electronic potentiometer and high-speed recorder. Specimen is subjected to brief but violent discharge. Polarization is recorded before and after discharge. Data are reproducable and distinctive for each set of corrosive conditions. It is used to evaluate inhibitors, to choose proper corrosion-resistant alloys, to determine corrosiveness of chemicals, and to control inhibitor concentration.—INCO.

Some Corrosion Tests on Tin (G). L. W. HAASE. *Metalloberflache,* 2, No. 8, 166-168 (1948) Aug.

Author tested tin foil in contact with soaps, paraffin oil, glycol and similar products, sodium percarbonate being added in some cases. There was no appreciable corrosion unless perxoide oxygen was present.—BNF.

First Report of the Methods of Testing (Corrosion) Sub-Committee. BISRA, Metallurgy (Gen.) Div., Paper MG, PF, 29, '47, Nov. 3, 1947. *J. Iron Steel Inst.*, **158,** Pt. 4, 463-493 (1948) Apr.; *Build. Sci. Abs.*, **21,** No. 7, 199 (1948).

Account of researches of the Committee on the basis of which Provisional British Standard No. 1391: 1947 "Performance Test for Protective Schemes Embracing Stoving Paints Used in the Protection of Light-Gauge Steel and Wrought Iron against Corrosion" was compiled. After investigations of different methods of testing, a sea-water spray test was selected as most suitable and was standardized. Tests were made on various types of stoving paint coating on phosphated or non-phosphated steel. Statistical aspects of the test are analyzed.—INCO.

WATER

Biological Aspects of Water Pollution. L. A. ALLEN. Paper before Ass'n of Applied Biologists, Mar. 22, 1948. *Nature,* **161,** No. 4101, 875 (1948) June 5.

In manufacture of beet sugar, practice of re-circulating waste waters to diffusers in order to avoid discharging them leads

to corrosion in re-circulation system. Investigation showed that this is due to formation of acid by thermophilic lactobacilli which can be prevented from growing by applying chlorine to contents of battery supply tank or by maintaining re-circulation system at a sufficiently high temperature.—INCO.

INDEX TO ADVERTISERS
DECEMBER, 1949

Vol. 5 No. 12

	Page
Allied Chemical & Dye Corp., Barrett Division	5
American Brass Co.	ix
American Cast Iron Pipe Co.	20
American Hot Dip Galvanizers Assoc.	10
Atlas Mineral Products Co.	18
Bechtel Corp. & H. C. Price Co.	x
Brance-Krachy Co., Inc.	11
Cathodic Protection Service	13 & 3
Cathodic Servicing Co.	15
Corrosion Engineering Co.	16
Crose, M. J., Co.	21
Day, S. D. Co.	3
Dearborn Chemical Co.	Inside Front Cover
Dow Chemical Co.	v
Dowell, Inc.	ii
Duriron Co., The	Inside Back Cover
Electro Rust-Proofing Co.	16
General Paint Co., Hill, Hubbell Div.	22
Huddleston Engineering Co.	3
Johns-Manville Co.	17
Koppers Co., Inc	4
Mayes Bros., Inc.	i
Middle West Coating & Supply	21
Midwestern Engine & Equip. Co.	viii
Minnesota Mining & Mfg. Co.	vi
Natasco Co.	14
National Assoc. of Corrosion Engrs.	v
National Carbon Co.	19
Nelson Electric Co.	2
Perrault Bros.	vii
Pittman, W. G.	14
Plastic Lining Corp.	3
Rosson-Richards Co.	3
Sims, C. I.	3
South Florida Test Service	3
Standard Pipeprotection, Inc.	7
Stearns, D. E.	Back Cover
Tapecoat Co., The	10
Tator, Kenneth, Associates	3
Thayer, Starr	3
Wilkinson Products Co.	6

First Complete Line of

CORROSION MITIGATION PRODUCTS

INCLUDING CATHODIC PROTECTION EQUIPMENT

Coal Tar Enamel . . Koppers Cold Coatings . . OK Glass Reinforcement . . Pipe Line Felts . . General Electric Rectifiers . . Apex Magnesium Anodes . . National Carbon Graphite Anodes . . Nelson Electric Flange Insulators . . Fasteners . . Etc.

ALL MATERIALS AND EQUIPMENT FOR CORROSION PROTECTION

A One-Call Service

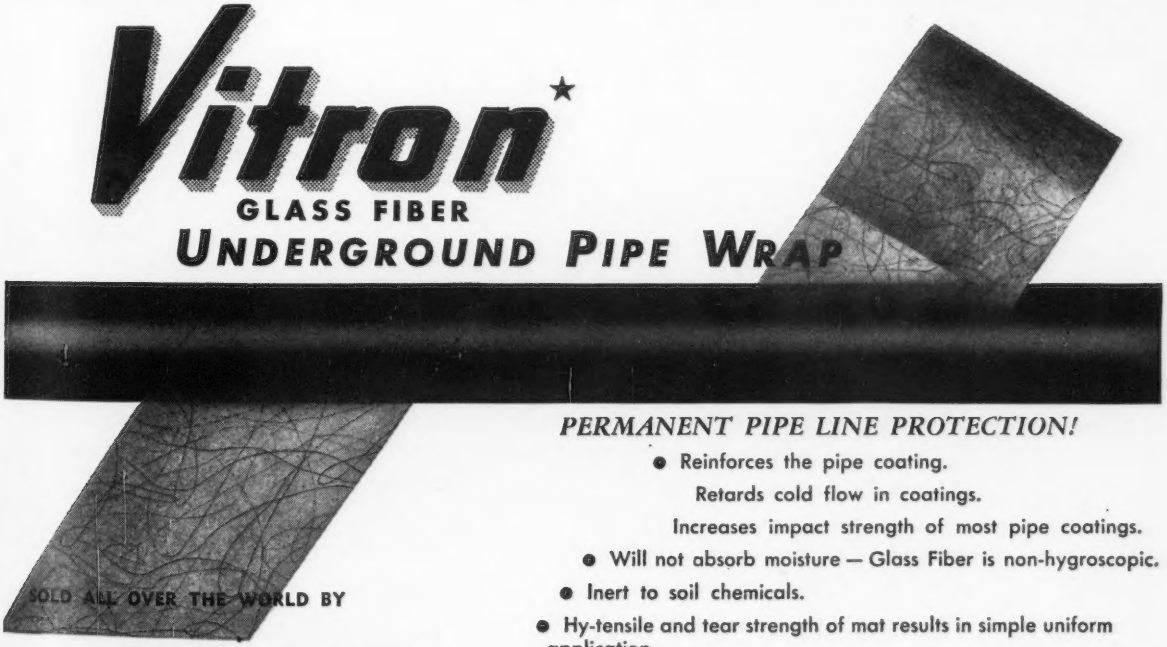
Distributor: OK GLASS REINFORCEMENT. Precision-made glass of uniform strength, uniform penetration, uniform in all qualities. A FABRIC—not a mat. Made by Oklahoma Glass Fiber Corp., Newport, Ark.

MIDDLE WEST COATING & SUPPLY

807 Daniel Bldg. TULSA, OKLA. Telephone 2-0865

MAYNARD H. JACKSON, Home Phone 7-5403

Vitron* GLASS FIBER UNDERGROUND PIPE WRAP



SOLD ALL OVER THE WORLD BY

M. J. CROSE MANUFACTURING CO., INC.

2715 Dawson Road, Tulsa, Okla.

Houston — New York — San Francisco

PERMANENT PIPE LINE PROTECTION!

- Reinforces the pipe coating.
  Retards cold flow in coatings.
  Increases impact strength of most pipe coatings.
- Will not absorb moisture — Glass Fiber is non-hygroscopic.
- Inert to soil chemicals.
- Hy-tensile and tear strength of mat results in simple uniform application.
- Excellent saturation characteristics with all types of pipe coatings.

WRITE FOR BULLETIN NO. V-69

**"VITRON is the registered trade mark of Glass Fibers, Inc., Waterville, Ohio."*

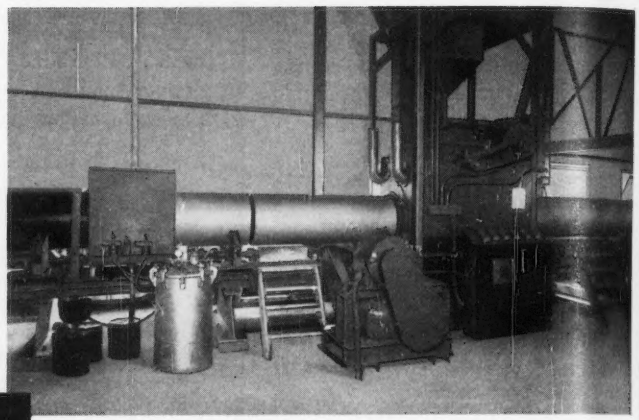
FAR LONGER PIPE LIFE

NOW! with Hill, Hubbell-engineered "Roto-Grit-Blast"... the industry's most advanced, most effective angular steel-grit blasting process!

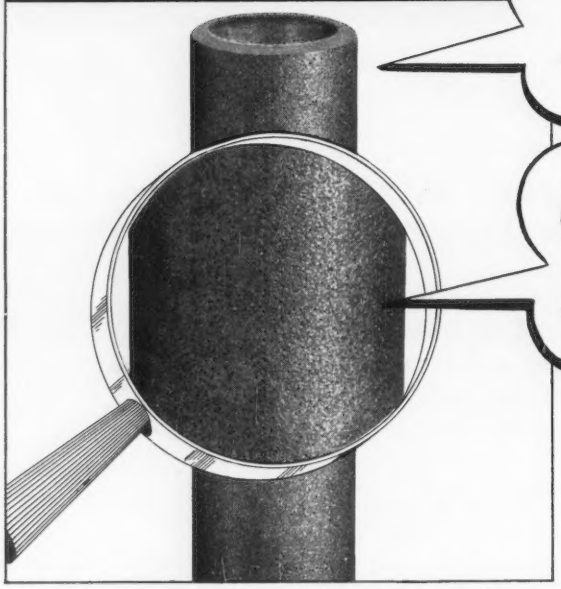
Corrosion authorities agree! The *foundation* for coating and wrapping is one of the most important factors in pipe life. Unless there is positive, *permanently-keyed* bond between pipe and primer, the coating and wrapping can easily fracture or even become entirely destroyed!

That is why Hill, Hubbell engineers developed "Roto-Grit-Blast"—the industry's most advanced method of pipe protection. Steel grits are blasted against the pipe surface, cleaning and etching it metal-bright to provide a *permanent* bond for coating and wrapping.

This *factory* method assures more than ever that Hill, Hubbell-protected steel pipe is *sealed and safeguarded* against every possible agent of corrosion!



"ROTO-GRIT-BLAST"— surest, most positive method of pipe preparation:



1 Removes every trace of mill scale, rust, dirt... leaves the pipe *METAL-BRIGHT DUST-CLEAN*

2 *ETCHES* the pipe to assure perfect, positive bond of primer, coatings!

"Roto-Grit-Blast" is still another reason why Hill, Hubbell is more than ever the PIONEER IN PIPE PROTECTION!

Send for ACTUAL SAMPLE of "Roto-Grit-Blasted" Pipe!

Hill, Hubbell and Company
Division of General Paint Corporation
3091 Mayfield Road, Cleveland 18, Ohio

E-12

Please send me an actual sample of steel pipe cleaned and etched by your "Roto-Grit-Blast" process of angular steel-grit blasting. Thank you.

Name _____

Firm _____

Address _____

City _____ State _____

Hill, Hubbell and Company
Division of GENERAL PAINT CORPORATION
3091 MAYFIELD ROAD, CLEVELAND 18, OHIO

Durco Announces: A MORE EFFICIENT SELF-PRIMING PUMP FOR CORROSIVE SERVICE

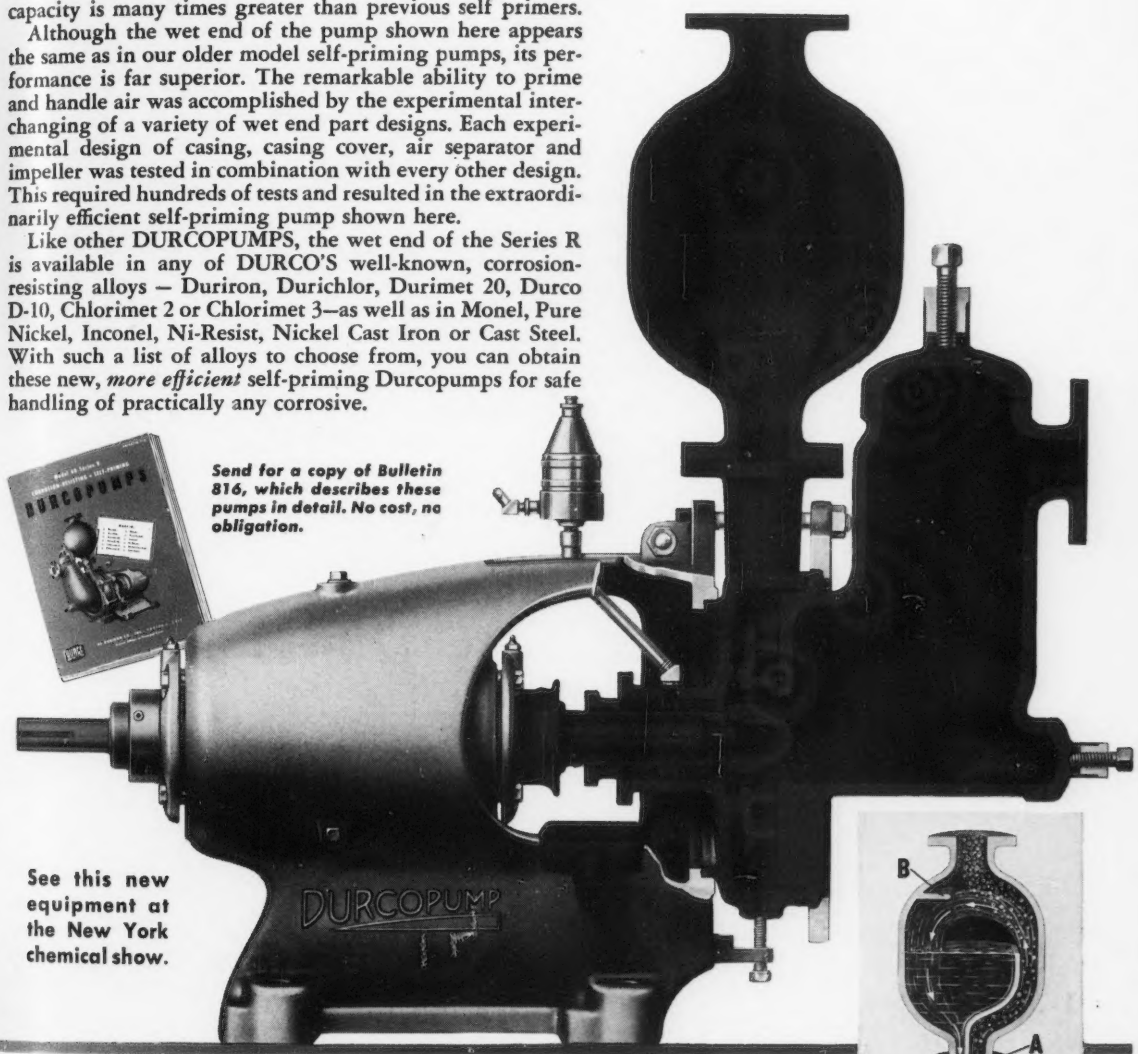
NEW DESIGN CUTS PRIMING TIME 66⅔%
AIR-HANDLING CAPACITY GREATLY INCREASED

As the result of twenty-five years of producing self-priming pumps and testing our own pumps and others, we say, "This is the finest self-priming pump available today for handling corrosive solutions."

Thoroughly tested in the field by customers, as well as in our own plant, test records show that priming time is only one-third that required by earlier models, and air-handling capacity is many times greater than previous self primers.

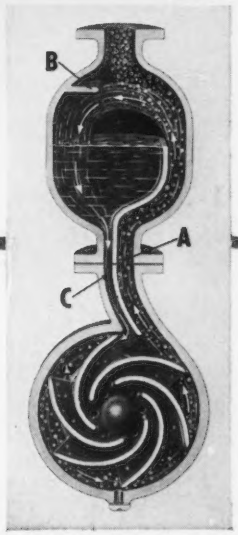
Although the wet end of the pump shown here appears the same as in our older model self-priming pumps, its performance is far superior. The remarkable ability to prime and handle air was accomplished by the experimental interchanging of a variety of wet end part designs. Each experimental design of casing, casing cover, air separator and impeller was tested in combination with every other design. This required hundreds of tests and resulted in the extraordinarily efficient self-priming pump shown here.

Like other DURCOPUMPS, the wet end of the Series R is available in any of DURCO'S well-known, corrosion-resisting alloys — Duriron, Durichlor, Durimet 20, Durco D-10, Chlorimet 2 or Chlorimet 3—as well as in Monel, Pure Nickel, Inconel, Ni-Resist, Nickel Cast Iron or Cast Steel. With such a list of alloys to choose from, you can obtain these new, *more efficient* self-priming Durcopumps for safe handling of practically any corrosive.



Send for a copy of Bulletin 816, which describes these pumps in detail. No cost, no obligation.

See this new equipment at the New York chemical show.



This drawing shows how the Series R DURCOPUMP operates in priming. When the pump is started, the water is thrown upward into the air separator through port A, while air is drawn in from the suction line at the eye of the impeller. Water and air pass into the air separator. The water, baffled by plate B, returns through port C. The air passes into the discharge line. When the air in the suction line is evacuated, the impeller discharges liquor through both ports A and C.

THE DURIRON CO., INC., DAYTON 1, OHIO

Branch Offices in Principal Cities

DURCO Adv. 102-GM

★ Thorough Inspection ★ Light Weight
★ Simple to Operate ★ Dependable Service

D. E. STEARNS
SHREVEPORT, LOUISIANA

POST OFFICE BOX 1234

A Dependable Organization
providing the
Finest Holiday Detector Equipment
for the
Entire Pipe Line Industry

Via Air - Anywhere

BETTER COATINGS CONSERVE STEEL